Pertanika 1(2), 112–119 (1978)

Floristic Components of the Ground Flora of a Tropical Lowland Rain Forest at Gunung Mulu National Park, Sarawak

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Key words: Floristic Components, Ground Layer, Lowland rainforest, Microhabitat, Distribution of tropical Herbaceous plants, Variegated foliage.

RINGKASAN

Komponen tumbuh-tumbuhan lapisan tanah yang berkiatan dengan mikrohabitat di Taman Negara Gunung Mulu Sarawak telah dihuraikan. Mikrohabitat pada sistem sungai merangkumi kawasan air cetek, tebing berbatu-batu, tebing sungai luas, dan mikrohabitat di-hutan teduh iaitu kawasan selalu lembah, lereng berbatu tanpa sarap, lereng curam bersarap, hutan lanar rata tersalir, permukaan kayu balak, akar dan batu dapat disiasat. Punca sebab yang mungkin menyebabkan penyibaran yang tak sama rata spesies-spesies di-lapisan tanah hutan lanar rata tersalir telah dibincangkan. Senari spesies hutan lanar ini juga telah dibanding-kan dengan senari spesies yang telah dilapurkan dalam penerbitan dari Lembah Danum Sabah, Hutan Simpan Pasoh Malaysia Barat dan lain hutan pamah di Sarawak, seperti kerangas *dan hutan paya gambut. Ke-hadiran daun berwarna pelangi dan beranika warna telah dicatitkan dengan ringkas.*

SUMMARY

The floristic components of the ground layer at the Gunung Mulu National Park, Sarawak, are described. These components are associated with microhabitats. The microhabitats of the riverine system include the shallow stream, rocky banks and banks of larger rivers, and those of the shaded forest include permanently wet areas, rocky litter-free slopes, steep litter covered slopes, surfaces of logs, roots or rocks and the flat well-drained alluvial forest. Possible causes of the uneven distribution of the ground layer species of the flat well-drained alluvial forest are discussed. The species composition of this alluvial forest is compared with other published reports from the Danum Valley, Sabah and Pasoh Forest Reserve Malaya, and with some other lowland forest types such as kerangas *and peat swamp forest in Sarawak. The phenomenon of iridescence and variegation of leaves is briefly noted.*

INTRODUCTION

The ground flora of the tropical rain forest (i.e. plants below 2m tall) lives in one of the most uniform environments, characterised by extremely low light intensity (about 1% of full sunlight), high humidity (90–100%) and constant temperatures and where the diurnal difference is greater than the annual. In spite of these constant environmental factors and the fact that many species have a wide geographic range, their distribution within the rain forest is by no means uniform. On the one hand, microhabitats can be distinguished that possess a distinctive floristic composition: on the other hand the distribution of plants of the flat alluvial forest shows no obvious pattern of distribution and large areas of the forest floor are devoid of herbaceous cover.

Information on the natural history and distribution of species of the ground flora of Malesian forests is limited to the local floras, except for Burtt's review (1977) on growth patterns and reproductive methods of the herbaceous flora. Although many ecological surveys of forest types have been carried out in Malaysia, these concentrate on the larger trees and information on the ground flora is often lacking. The survey described here is based on five week's fieldwork in the lowland alluvial forest of the Gunung Mulu National Park, Sarawak (Fig. 1).

General descriptions of the ground flora of tropical rain forest (Richards, 1952, Burtt, 1977) mention the predominance of certain families: Araceae, Begoniaceae, Cyperaceae, Gesneriaceae and Melastomaceae (at Mulu, Acanthaceae and Rubiaceae are also common) and comment that the number of families and species involved is very much less than those of the tree layers, probably due to the less favourable conditions for plant growth imposed by the deep shade;

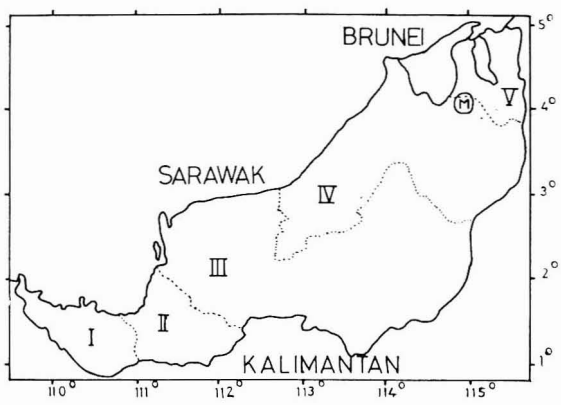

Fig. 1. Map of Sarawak to show the location of the Gunung Mulu National Park (M).

but that several genera are obviously successfully adapted to these conditions and possess many species e.g. *Begonia* (Begoniaceae)and *Cyrtandra* (Gesneriaceae). While these families are herbaceous, there is also an important component of the ground flora which is woody, i.e. the diminutive palms (in particular the genera *Pinanga, Iguanura* and *Licuala*) *Euthemis* (Ochnaceae) and *Driessenia* (Melastomaceae). Apart from the angiosperm flora, ferns and *Selaginella* are important, though there is a noticeable absence of ground mosses as compared (for example) with *kerangas*[1] forest where they form a conspicuous feature of the ground flora.

Floristic components of the ground flora

Within the lowland forest at Mulu several microhabitats can be distinguished which possess a characteristic assemblage of species. Broadly these can be grouped into those in which the canopy is open (Table 1), for example, along streams; in contrast with those in which the canopy is closed (Table 2).

Within the undisturbed forest, the canopy over streams is sometimes not complete and direct sunlight can reach a restricted area of the forest floor. Two such streams were observed in the study area (Table 1A) where the characteristic species include *Alocasia* aff. *macrorrhiza* (L.) Schott. which is aquatic and also appears light-demanding; and *Curculigo latifolia* Dryand., which although relatively light-demanding, requires better drained soils and thus is common on stream-banks. The steep, almost vertical, rocky banks of torrential streams carry a characteristic flora (Table 1B). A 50m long portion of the bank on the Sungai Tabaun (Fig. 2) was sampled intensively and the general results for species composition and relative abundance were compared and confirmed by observation along the Melinau Gorge. The lower part of the rocky bank was subjected to intermittent flooding after rain, and here *Piptospatha elongata* N.E. Brown was abundant (and confined to this habitat). Also present was a species of *Sonerila* and small plants of *Myrmeconauclea strigosa* (Korth.) Merr., which in this habitat did not appear to grow to adult size or to flower. Above the flood level, *M. strigosa* was the commonest plant, with its characteristically horizontal branches reaching over the river. In addition there were eight other species of flowering plants (Table 1B), seven species of ferns and one species of *Selaginella*. Above the rocky bank at Sungai Tabaun, towered the damp shaded vertical rock face of the gorge which was completely covered by plants of *Hexatheca fulva* C.B.Cl., many with snowy white flowers. *Epithema involucratum* (Roxb.) Burtt occurred on rocks in the river.

Another riverine association was found along the banks of the larger rivers especially on banks which were wide and where small boulders had accumulated. These observations were made below the Melinau Gorge (Fig. 2). Here the shrub layer was very dense, frequently covered by a variety of flowering woody creepers (Table 1C) and a few herbaceous climbers, such as species of *Aeschynanthus* (Gesneriaceae) and *Hoseanthus lobbii* (Verbenaceae). Only in open areas, e.g. where there was a clearing, were herbs able to flourish. Some of these species are light-demanding and become relatively large: *Musa campestris* Becc., *Donax canniformis* (Forst.) K. Schum. and *Costus speciosus* (Koenig) J.B. Smith, for example, attain a height of 2m. However, the species diversity of the ground flora of this habitat is poor.

Within the lowland forest itself, where the canopy is complete, several distinct microhabitats can be recognised by their characteristic assemblage of species (Table 2). These include a) permanently wet areas, b) rocky litter-free slopes, c) epiphytes on logs, roots or boulders, d) steep litter-covered slopes and e) the flat alluvial forest. The wet areas probably never dry out, because at Mulu the rainfall is distributed evenly throughout the year (J. Procter, pers. comm.). They also are likely to be subjected to frequent waterlogging; about 0.5m of standing water was observed after a night of heavy rain in one such area. These areas are conspicuous for the dense cover of the ground layer, often with a single species dominating, such as *Alpinia glabra* Ridl.

[1] *kerangas* forest is defined by Brunig (1975) as "Tropical lowland forests on infertile soil derived from base-poor parent material."

FLORISTIC COMPONENTS OF GROUND FLORA AT GUNUNG MULU, SARAWAK

TABLE 1

Ground layer species associated with riverine systems.

A. **Shallow streams**

Acanthaceae: *Staurogyne setigera* Nees. O. Kunzte

Araceae: *Alocasia* aff. *macrorrhiza* (L.) Schott.

*Begoniaceae: *Begonia* sp. i
Begonia sp. ii

Campanulaceae: *Pentaphragma acuminata* Airy Shaw

Hypoxidaceae: *Curculigo latifolia* Dryand

Urticaceae: *Elatostema sesquifolium* (Bl.) Hassk.

B. **Rocky banks of torrential streams**

Araceae: *Homalomena sagittifolia* Jungh. Schott
Piptospatha elongata N. E. Brown

Gesneriaceae: *Epithema involucratum* (Roxb.) Burtt
Hexatheca fulva C.B.Cl.

Marantaceae: *Stachyphrynium* sp.

Melastomaceae: *Sonerila* sp. i

Ochnaceae: *Neckia serrata* Korth.

Rubiaceae: *Argostemma* sp.
Myrmeconauclea strigosa (Korth.) Merr.

Urticaceae: *Elatostema sesquifolium* (Bl.) Hassk.

C. **Banks of wide rivers**

Shrubs (including small or young trees):

Capparidaceae: *Cratera nurvala* Ham.

Dilleniaceae: *Dillenia suffruticosa* (Griff.) Martelli

Leeaceae: *Leea aculeata* Bl.

Melastomaceae: *Medinilla crassifolia* Bl. (epiphyte)

Piperaceae: *Piper caninum* Bl.

Polygalaceae: *Polygala venenosa* Juss.

Sonneratiaceae: *Duabanga moluccana* Bl.

Rubiaceae: *Myrmeconauclea strigosa* (Korth.) Merr.
Psychotria crassifolia Miq.

Climbers:

Convolvulaceae: *Merremia peltata* (L.) Merr.

Cucurbitaceae: *Trichosanthes trifoliolata* V. Merell

Gesneriaceae: *Aeschynanthus parvifolius* R. Br.
A. tricolor Hook. f.

Oleaceae: *Jasminum crassifolium* Bl.

Rubiaceae: *Uncaria* sp.

Smilacaceae: *Smilax odoratissima* Bl.

Verbenaceae: *Hoseanthus lobbii* (Cl.) Ridl.
Vitex pubescens Vahl.

Vitidaceae: *Vitis cinnamomea* Wall.

Herbs:

Araceae: *Amorphophallus* sp.

Gramineae: *Centotheca lappacea* (L) Desv.

Marantaceae: *Donax canniformis* (Forst.) K. Schum.

Musaceae: *Musa campestris* Becc.

Palmae: *Pinanga riparia* Becc.

Pandanaceae: *Pandanus* sp.

Rubiaceae: *Acranthera frutescens* Val. ex Winkler

Zingiberaceae: *Costus speciosus* (Koenig) J. E. Smith

(* These families are under revision at Kew Gardens, London).

or *Hanguana malayana* Merr. – which are monocotyledons and spread by means of suckers or rhizomes. *Iguanura melinauensis* Kiew is frequent in this habitat and its seedlings must be able to withstand submersion. *Polyalthia flagellaris* (Becc.) Airy-Shaw, a small annonaceous tree with deep red flowers and fruits on short knobbly twigs above ground level, is conspicuous in this habitat.

Rocky slopes, although small in area, support a specific ground flora (Table 2B) including species of *Selaginella* and Hymenophyllaceae. These slopes are steep, with a crumbling rock surface without leaf litter. The species composition appears uniform from the two areas observed (which were 8km apart) (Fig. 2), and several species such as *Driessenia axanthera* Korth,. *Homalomena humilis* var *ovalifolia* Hotta, and *Phyllagathis elliptica* Stapf appear to be exclusive to such areas. On rocky slopes in narrow gulleys, damper conditions prevailed and *Begonia* species were more conspicuous. *Neckia serrata* Korth., by contrast, is a common and very widespread species which is also found on rocky banks of streams, suggesting that it is tolerant of lighter conditions, but is apparently intolerant of an accumulating litter layer as it is also found on the forest floor clear of litter. *Neckia serrata* is atypical in this respect as no

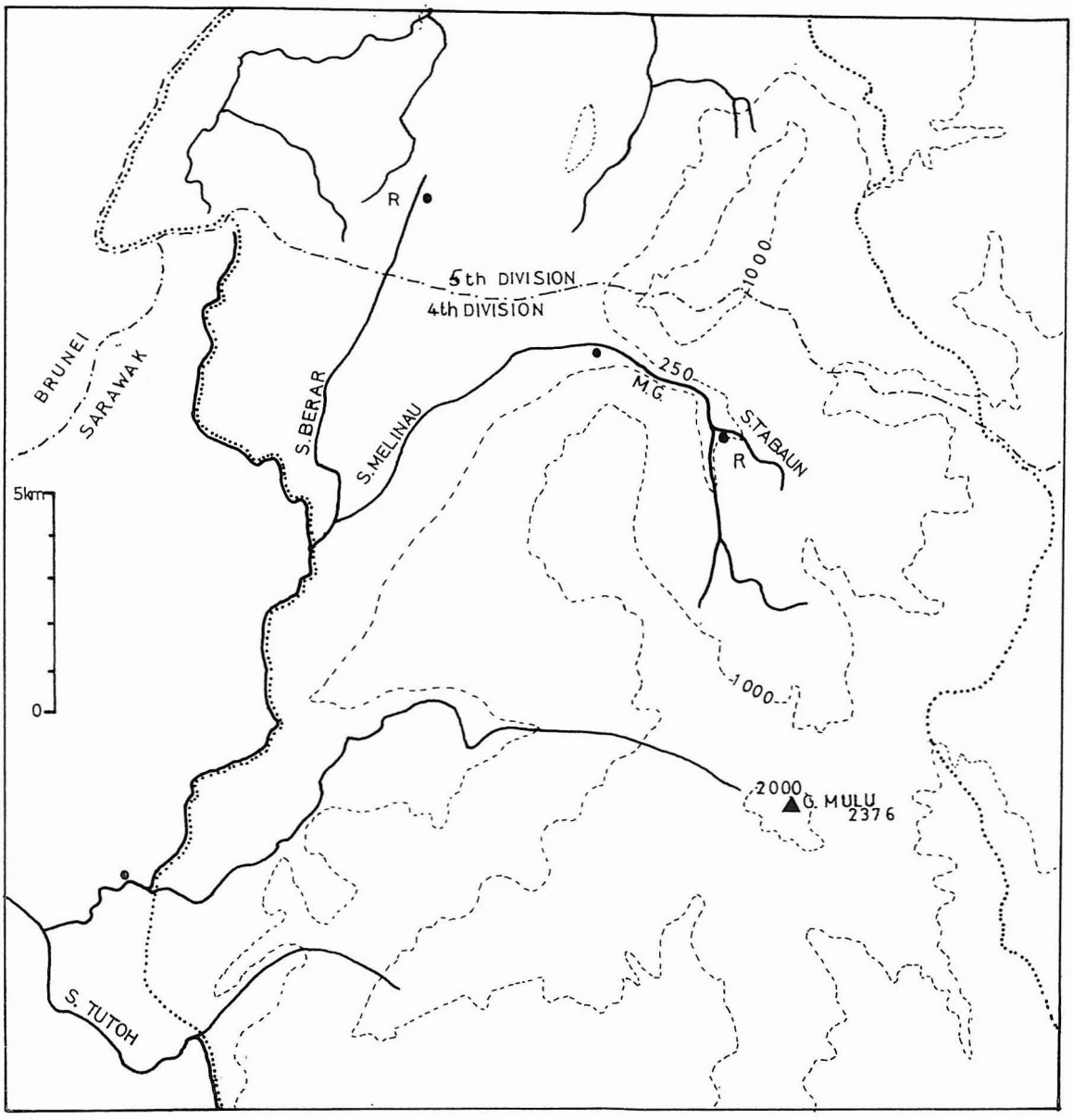

Fig. 2. Map of the Gunung Mulu National Park, Sarawak.
(M.G. Melinau Gorge; ● camps; R sites of rocky slopes and ridges).

other species of this assemblage also grows by streams.

The epiphytes of the ground layer of the lowland forest occupy two habitats: fallen logs, buttresses and raised tree roots or boulders, which at Mulu are generally limestone and which are frequently completely covered by herbs. Of these species (Table 2C) only *Elatostema acuminata* (Poir) Brongn. appears to be widespread and is found both on raised tree roots and boulders. *Cyrtandra oblongifolia* (Bl.) C.B.Cl., a species of *Sonerila* and *Lobelia zeylanica* L. appear as small, solitary plants on fallen logs. The remaining species which were found on limestone rocks were larger plants and spread over the rock surface by rooting at the nodes. Limestone boulders are often completely covered by epiphytes probably because the depressions on their surface retain water and perhaps allow litter accumulation.

TABLE 2

Ground layer species associated with shaded forest habitats.

A. **Permanently wet areas**

Araceae: *Homalomena insignis* N. E. Br.
Flagellariaceae: *Hanguana malayana* Merr.
Palmae: *Iguanura melinauensis* Kiew
Zingiberaceae: *Alpinia glabra* Ridl.
Achasma megalocheilos Griff.
Geanthus fimbriobracteatus (K. Schum.) Burtt & Smith

B. **Rocky, litter-free slopes**

Araceae: *Homalomena humilis* Hook. f. var. *ovalifolia Hotta*
*Begoniaceae: *Begonia* sp. iii
Begonia sp. iv
Begonia sp. v
Begonia sp. vi
Melastomaceae: *Driessenia axantha* Korth.
Phyllagathis elliptica Stapf
Ochnaceae: *Neckia serrata* Korth.
Rubiaceae: *Argostemma borragineum* Bl.
Triuridaceae: *Sciaphila flexuosa* Giessen

C. **Epiphytes on logs, roots, and boulders**

Acanthaceae: *Hallieracrantha salicifolia* Stapf
*Begoniaceae: *Begonia* sp. vii
Burmanniaceae: *Burmannia championii* Thw.
Campanulaceae: *Lobelia zeylanica* L.
Gesneriaceae: *Cyrtandra incrustata* (Bl.) Burtt
C. oblongifolia (Bl.) C.B.Cl.
Loxocarpus sp.
Melastomaceae: *Sonerila* sp. ii
Rubiaceae: *Argostemma havilandii* Ridl.
Ophiorrhiza fibrillosa Ridl.
Urticaceae: *Dendrocnide stimulans* (L.f.) Chew (shrub)
Elatostema acuminata (Poir) Brongn.

D. **Steep litter-covered slopes**

Shrubs and small trees:
Annonaceae: *Goniothalamus malayanus* Hook. f.
Araceae: *Alocasia denudata* Engl.
Gnetaceae: *Gnetum gnemon* var. *tenerum* Markgraf
G. macrostachyum Hook. f. (Liana)
Melastomaceae: *Phaulanthus acuminatissimus* Ridl.
Myrsinaceae: *Ardisia javanica* DC
Palmae: *Eugeissona utilis* Becc.
Rubiaceae: *Cephalis stipulaceae* Bl.
Herbs:
Asclepiadaceae: *Hoya parasitica* Wall. (climber)
Gesneriaceae: *Cyrtandra bracheia* Burtt
C. pendulifera Kraenzl
Loxocarpus verbeniflos (C.B.Cl.) Burtt
Marantaceae: *Stachyphrynium* sp.
Melastomaceae: *Sonerila pulchella* Stapf
Sonerila sp. iii
Ochnaceae: *Euthemis leucocarpa* Jack
Neckia serrata Korth.
*Palmae: *Areca tenella* Becc.
Licuala sp.
Pinanga tomentella Becc.
P. disticha (Roxb.) Wendl.
Pinanga sp.ii
Pinanga sp. iii
Pinanga sp. iv (variegated)
Rubiaceae: *Argostemma psychotrioides* Ridl.
Zingiberaceae: *Alpinia* sp. i
Alpinia sp. ii
Boesenbergia sp.
Plagiostachys sp.

E. **Flat, well-drained alluvial forest**

Acanthaceae: *Cosmianthemum magnifolium* Bremekamp
Staurogyne setigera Nees. O. Kuntze
Campanulaceae: *Pentaphragma cyrtandriforme* Airy Shaw
Commelinaceae: *Forrestia marginata* Hassk.
Cyperaceae: *Mapania cuspidata* (Miq.) Uttien
Gesneriaceae: *Cyrtandra radiciflora* C.B.Cl.
Marantaceae: *Stachyphrynium* sp.
Phrynium capitatum Willd.
Orchidaceae: *Calanthe triplicata* (Willem.) Ames
Malaxis aff. *nemoralis* (Ridl.) Holttum
Plocoglottis aff. *javanica* Bl.
Palmae: *Iguanura melinauensis* Kiew
Piperaceae: *Piper porphyrophyllum* N.E.Br.
Polygalaceae: *Epirixanthes cylindrica* Bl.
E. elongata Bl.
Rubiaceae: *Acranthera involucrata* Val.
Argostemma psychotrioides Ridl.
Lasianthus stipularis Bl. (small shrub)
Myrioneuron cyaneum Hall. f.
Ophiorrhiza communis Ridl.
Streblosa bracteata Ridl.
Taccaceae: *Tacca* sp.
Triuridaceae: *Sciaphila flexuosa* Giessen
Urticaceae: *Elatostema acuminata* (Poir) Brongn.
E. variolaminosum Schroeter
Zingiberaceae: *Boesenbergia pulchella* Ridl.
Geostachys sp.
Globba atrosanguinea T & B

* These families are under revision at Kew Gardens, London

The assemblage of plants found on litter covered steep slopes and ridges (Table 2D) has few species in common either with rocky slopes (where litter does not accumulate) or with the low undulating alluvial forest floor. This is particularly true of the gingers which appear to have quite strict requirements for water. Exceptions are *Argostemma psychotrioides* Ridl. and *Stachyphrynium* (which also grow in the flat alluvial forest) and *Neckia serrata* Korth. (which grows on shaded rocky slopes and exposed rocky stream banks). Richards (1936) noted that there was a difference in the abundance of herbs on ridgetops (four times as many) than on slopes, which he suggested could be due to the more open canopy of ridge tops increasing the light intensity at ground level. From observation at Mulu, undergrowth palms are more abundant on the ridges than on the slopes. However, some species such as *Cyrtandra pendulifera* Kraenzl and *Sonerila pulchella* Stapf, which appear as dense though small populations, appear specific to steep slopes. It is difficult to explain the differences between the two ridges at Mulu (Fig. 2). One supported a varied flora of about fourteen herbaceous species (Table 2D) while the other at Sungai Berar supported a few sterile plants of *Stachyphrynium, Pandanus* and gingers; though both supported a rich palm flora. Both ridges were apparently similar in slope, the only significant difference being that the latter ridge was shale.

The flat well-drained alluvial forest covers a greater area than any of the other microhabitats described above and its flora is correspondingly diverse (Table 2E). Compared with the habitats described above, the plants are in general less frequent and give an impression of a large area of bare ground. A few of these species (Table 2E) such as *Cyrtandra radicifolia* C.B.CL. and *Lasianthus stipularis* Bl. form dense stands in particular areas. It is very difficult though to discern any difference between the areas where they occur and the areas from which they are absent. This is also true in the case of other species which show a patchy distribution. Some are represented by individuals, such as the ground orchids or species of *Acranthera,* while others are found as isolated populations, such as *Ophiorrhiza communis* Ridl., *Argostemma psychotriodes* Ridl. and *Streblosa bracteata* Ridl.

Distribution of the ground flora of the alluvial forest

The patchiness of the ground flora of the flat well-drained alluvial forest has been ascribed to three causes: the predominance of vegetative reproduction (Richards, 1952, Walters, 1955), the lack of pollination (van Steenis, 1969) and the failure of seedling establishment (Burtt, 1977). Richards (1952) considered species growing under the closed canopy as shade-loving and suggested that vegetative reproduction was more important in those species than reproduction by seed. In this survey there was no evidence for this claim as the great majority of the species could be found flowering or fruiting. The main exception was the Araceae. Many aroid species though frequently sterile, occur as solitary plants, which suggests that they are the product of seed dispersal. Burtt considers that vegetative reproduction is the cause of gregariousness and contrasted the vegetative spread in monocotyledons by suckers or rhizomes with that of the dicotyledons where clumps result because the tall aerial stems eventually become decumbent, root and produce aerial shoots. This is supported by the observations in this survey. These gregarious species *(Argostemma, Streblosa* and *Elatostema)* were as free flowering as the solitary species, such as *Acranthera, Neckia* and *Sonerila.*

Insufficient pollination was suggested by van Steenis (1969) as a limiting factor in the distribution of basally flowering trees, such as Apocynaceae and Bignoniaceae based on observations that they rarely set fruit. This is not true for the ground layer. Careful examination of plant populations in the field shows that most species produce fruits but they often tend to be inconspicuous and thus may be overlooked. One notable exception from Malaya is *Lepidagathis longifolia* Wight which Ridley (1923) quotes as being abundant but "no one as yet has ever seen a fruit, and it would not fruit in Singapore Gardens". Henderson (1959) mentions that none of the specimens of this species in the Singapore Herbarium had fruits. Many of the species observed at Mulu possessed both flowers and fruits on a single plant suggesting that flowering is more or less continuous.

Failure of seedling establishment is difficult to assess, because seeds collected in the field and germinated in pots often show high viability (Kiew, 1972, Burtt, 1977), whereas in the field, seedlings are often rare. The most conspicuous seedlings in the ground layer are those of various species of palms, most of which belong to Lepidocaryoid rattan genera but arecoid species are well represented. The undergrowth palms are often solitary and rely on sexual production for survival. Perhaps the infrequency of seedlings of other species indicates that seedling establishment is the critical phase in their life history. In this case, vegetative reproduction can be viewed as a method of prolonging the life of the individual plant, thereby increasing the quantity of seed that a single plant can produce and so increasing its chances of replacement. The mode of dispersal

of the small dry seeds of these dicotyledonous herbs such as Gesneriaceae, Begoniaceae, Rubiaceae and Melastomaceae is not known. Burtt suggests that dispersal is effected by rainwash or by being carried on the feet of animals (wind dispersal is impossible, since wind movement in the undergrowth is negligible). However, in conditions outside the forest similar sized seeds belonging to rubiaceous weed genera such as *Borreria* are effectively dispersed as is evidenced by their abundance and rapid spread since their introduction, e.g. B. alata (Aubl.) DC. (B. latifolia) first noticed in Singapore in 1915 (Ridley, 1923) is now a widespread weed in Malaya. It is not known how its seeds are dispersed. In this survey, *Iguanura melinauensis* Kiew, was found to be a conspicuous example of a plant with a local distribution: it is common along the Sungai Melinau but is absent from the adjacent Sungai Berar.

Many of the undergrowth species show widespread geographic distribution, which indicates that in the long term their mode of dispersal is effective. However, their patchy distribution within the undergrowth and the dearth of seedlings suggest that the seedling establishment phase is the critical one in most cases. The reason for this is not known. Perhaps predation of fruit might account for the lack of seedlings, rather than attack of the seedlings; most adult plants appear free of fungal and insect attack with the notable exception of *Streblosa bracteata* Ridl. which has most of its leaves perforated due to insect damage in the bud. Competition with tree roots for water in the soil surface might also be a limiting factor as the only closed herbaceous communities are found in areas which are permanently wet.

There are a few species with an apparently scattered and widespread distribution, though they are nowhere common, e.g. *Globba atrosanguinea* T & B, *Epirixanthes elongata* Bl. and *Acranthera involucrata* Val.. The distribution of a few species is correlated with soil conditions, as mentioned above. *Neckia serrata* requires a litter-free habitat, and *Mapania cuspidata* (Miq.) Uttien grows on more acid soils. The majority of species, however, have distributions which apparently have been determined more by chance.

Comparison of ground flora at Mulu with other areas and forest types

Comparison of the ground flora at Mulu with other areas is difficult because whereas the ground flora at Mulu has been well collected over the years, very few other areas are equally well known or published information is lacking. More significant is the absence of certain species which are common in other areas. The Danum Valley (Sabah) expedition botanical report on ground flora (Kiew, 1977) based on B.C. Stone's collections, shows a close similarity to that as Mulu and is particularly useful for its descriptiont of the ridge, valley, riverine and gulley habitats: the species composition matches that of Mulu closely. For Malaya, no detailed studies of the herbaceous flora are reported. Soepadmo and Kira (1977) in a brief summary of common families and genera of the ground flora at Pasoh F.R., Malaya, include *Dracaena* (correctly *Pleomele*) (Agavaceae), *Phyllagathis* (Melastomaceae) and *Labisia* (Myrsinaceae) which are common plants of the Malayan undergrowth. Species of *Phyllagathis* and *Labisia* were not collected from the Danum Valley, and neither is common at Mulu, whereas several species of *Phyllagathis* are abundant in the Malayan alluvial forest. At Mulu the one species of *Phyllagathis* collected was confined to rocky litter-free slopes. In contrast, species of *Acranthera,* which are widespread in Borneo, are not recorded from Malaya (Ridley, 1923). However it is not unknown for different species of a genus to behave differently in separate localities, as in *Iguanura* (Kiew, 1976) where *I. wallichiana* in Malaya is common and widespread while in Sarawak no *Iguanura* species is widespread and many have extremely local distributions, c.f. *I. melinauensis*.

Comparison of species diversity in this Mulu lowland forest ground flora with other forest types is difficult. This study is based on observation of about 5km^2, while the detailed studies of Brunig (1974) on *kerangas* forest and Anderson (1963) on peat swamp forest include data from all available sites in Sarawak. The 105 species of the ground flora collected at Mulu is an underestimation for the total ground flora of Sarawak as the exclusion of unidentified sterile plants underrepresents the Araceae, Orchidaceae and Zingiberaceae, and those species with a local distribution outside this study area were not included. Even so, the species diversity is very much higher than that of *kerangas* forest (69 species) and peat swamp forest (19 species). Compared with these two forest types, the alluvial forest is rich in species of Gesneriaceae, Begoniaceae *(Begonia)* and Urticaceae *(Elatostema)* but is poor in Nepenthaceae *(Nepenthes),* which is well represented in the other two forest types. The *kerangas* resembles the alluvial forest in its Melastomaceae, Rubiaceae, Palmae and Zingiberaceae which were well represented. In contrast there are only three species of Araceae, although the Cyperaceae with eleven species is better represented. The ground flora of the peat swamp forest can be expected to be low in species as much of the area is permanently submerged.

Several characteristic families of the ground layer of alluvial forest such as Acanthaceae, Melastomaceae, Orchidaceae and Rubiaceae are absent, none the less the Araceae is as well represented as in the alluvial forest though by different species. The lower species diversity of the *kerangas* and peat swamp forest can be ascribed to their environment offering less favourable conditions for plant growth. *Kerangas* forest is poor in nutrients and has a low pH and the swamp conditions of the peat swamp forest exclude those plants that require well drained soil.

The incidence of iridescent and variegated foliage

Most authors comment on this conspicuous feature of the ground flora noting that it is not seen in other layers of the forest. In fact very few species are involved and these are confined to even fewer families. Iridescence is common in some species of *Selaginella,* e.g. *S. willdenowii,* in which Lee and Lowry (1975) showed that the iridescence was due to lens-shaped epidermal cells which they suggested are advantageous in absorbing a wider spectrum of light intensities in the deep shade. Iridescent foliage is also known in some ferns, some begonias and species of *Mapania,* Cyperaceae (Burtt, 1977).

Plants with variegated leaves (with white, yellow or reddish blotches, spots or lines) are more common than plants with iridescent foliage. At Mulu, genera with variegated leaves included *Begonia, Sonerila, Alocasia, Plocoglottis, Malaxis, Pinanga, Piper* and *Pleomele* (the latter collected by Stone, pers. comm.). Some of these species were constant in their variegation, such as *Plocoglottis javanica* Bl. with its white spots and *Malaxis nemoralis* (Ridl.) Holttum with its ginger-coloured leaves; others such as *Sonerila pulchella* Stapf occurred as local populations and varied in the proportion of individuals with variegated leaves. Hibbert (1870) illustrates cultivated examples, several of which belong to the Acanthaceae. Although herbaceous species of the Acanthaceae are common in the ground layer, relatively few species are variegated, as for example *Gymnostachyium magis-nervatum* C.B.Cl. and *Polytrema cupreum* Ridl. from Malaya but no variegated examples of this family were collected at Mulu. Some of these species undoubtably have horticultural potential, in particular the begonias. Dransfield (1974) has introduced several species of variegated pinangas (where the variegation takes the form of an attractive marbling of the leaves) into cultivation at the Bogor Botanic Gardens. Trial cultivation is necessary for the other species to determine their horticultural value.

ACKNOWLEDGEMENTS

I wish to express my gratitude to the Royal Geographical Society for permission to participate in the Gunung Mulu (Sarawak) Expedition; to Universiti Pertanian Malaysia for the research grant which enabled me to participate; to Mr. Paul Chai, Forest Botanist, for providing facilities at the Forest Department, Kuching and to Dr. B.C. Stone for his helpful criticisms of this paper.

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(*Received 23 August 1978*)