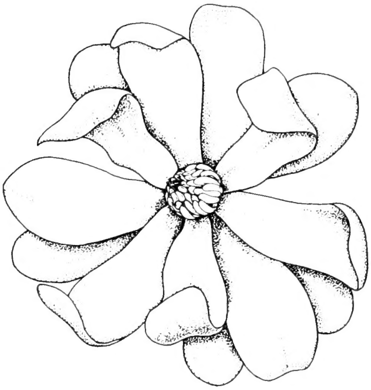

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## SINGAPORE

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# A Phylogenetic Classification of Ophioglossaceae

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## Abstract

A cladistic approach was undertaken to construct a phylogenetic classification of the Ophioglossaceae. The characters used are: rhizome, stele, leaf sheath, size and cutting of trophophyll, vascular branching in leaf axes, venation, position of sporophyll on trophophyll, form and construction of sporophyll, position and dehiscence of sporangia, and suspensor. Character state, primitive (plesiomorphic) vs. advanced (apomorphic), was estimated for each character. Based on presumed character phylogenies, a cladogram representing phylogenetic relationships was drawn. Although in previous classifications (e.g. Clausen, 1938) the Ophioglossaceae were classified into three genera, *Botrychium, Helminthostachys* and *Ophioglossum,* it is contended here that the genus *Botrychium sensu* Clausen is not a monophyletic group. In this paper I propose a new classification recognizing six genera and arrange them as in Cracraft's (1974) sequence as follows: 1 (most primitive), *Botrypus;* 2, *Japanobotrychium;* 3-1, *Sceptridium;* 3-2, *Helminthostachys;* 4, *Botrychium;* 5 (most advanced), *Ophioglossum.*

The Ophioglossaceae have a combination of unique or rare morphological characters among the extant lower vascular plants: three-dimensional leaf architecture, collateral vascular bundles (sympodial vascular system; Stevenson, 1980) with secondary growth in many species, hair-lacking roots with endophytic fungi, noncircinate vernation of leaves, a soft and fleshy plant body devoid of sclerenchyma, massive eusporangia, and subterranean, mycorrhizic, massive gametophytes of fundamentally axial organization (Bierhorst, 1971; Foster and Gifford, 1974). Because of those characters the family is regarded as an isolated group composing the monotypic order Ophioglossales.

The usual systematic treatment is that the Ophioglossales, along with the Marattiales, constitute a eusporangiate group in Filicopsida or ferns (e.g. Christensen, 1938; Eames, 1936; Smith, 1955), or the order is one of three or more orders composing Filicopsida (e.g. Copeland, 1947; Foster and Gifford, 1974; Pichi Sermolli, 1973: Tryon and Tryon, 1982). However, a real relationship of the Ophioglossales with the Marattiales and also Filicales is doubted by some authors (Bierhorst, 1971; Kato, 1982, 1983). To determine the phylogenetic position of the Ophioglossaceae in the vascular plants, it is needed to better understand the phylogenetic relationships within the family.

The currently accepted classification of the Ophioglossaceae (e.g. Copeland, 1947; Tryon and Tryon, 1982) is mainly that of Clausen (1938) who recognized the genera *Botrychium, Helminthostachys* and *Ophioglossum* in the family. He classified *Botrychium* in three subgenera (*Osmundopteris, Sceptridium* and *Botrychium*) with seven sections, and *Ophioglossum* into the four subgenera *Ophioglossum, Rhizoglossum, Cheiroglossa* and *Ophioderma.* In his revised system, Nishida (1952) divided the Ophioglossales into two suborders, Ophioglossineae and Botrychiineae. The Ophioglossineae consisted of four genera, *Ophioglossum, Ophioderma, Cheiroglossa* and *Rhizoglossum,* belonging to the one family Ophioglossaceae, while the Botrychiineae comprised two families, Botrychiaceae with the genera *Botrychium, Sceptridium* and *Osmundopteris* (= *Botrypus*), and Helminthostachyaceae with the sole genus *Helminthostachys.* Following Clausen

Table 1. Characters in Ophioglossaceae

| Code | Character | *Botrypus* | *Japanobotrychium* | *Sceptridium* | *Helminthostachys* | *Botrychium* | *Ophioglossum* |
|---|---|---|---|---|---|---|---|
| 1 | Rhizome | radial | radial | radial | dorsiventral | radial | radial |
| 2 | Vascular cambium | + | + | + | – | + | – |
| 3 | Leaf sheath covering | incomplete | complete | complete | complete | complete with fused slit | complete with oblique slit |
| 4 | Trophophyll size | +++ | +++ | ++ | ++ | + | + |
| 5 | Trophophyll dissection | ++++ | ++++ | +++ | ++ | ++ | + |
| 6 | Vascular branching in leaf axis | extra-marginal | extra-marginal | extra-m./marginal | extra-m./hetero-marginal | marginal | marginal |
| 7 | Venation | free | free | free | free, parallel | free, parallel | anastomosing |
| 8 | Sporophyll position | stipe top | lower part of rachis | lower to upper part of stipe | stipe top | stipe top | stipe top (stipe base, lamina) |
| 9 | Sporophyll form | foliar | foliar | foliar | spike | foliar | spike |
| 10 | Sporophyll construction | 2-dimensional | 2-d. | 2-d. | 3-d. | 2-d. | 2-d. |
| 11 | Sporangium position | terminal | lateral | lateral | lateral | lateral | embedded |
| 12 | Sporangium dehiscence | longitudinal/ subtransverse | transverse | transverse | transverse | transverse | transverse |
| 13 | Suspensor | – | – | + | + | – | – |

(1938) in general scheme, Kato and Sahashi (1977) recognized a fourth subgenus *Japanobotrychium* in genus *Botrychium,* which had been treated as a section of subgenus *Osmundopteris* by Clausen (1938).

The classification of Ophioglossaceae is still controversial, however. Many authors consider *Sceptridium* the most primitive, and *Botrypus* (= *Osmundopteris*) and *Botrychium sensu stricto* advanced, mainly from morphological characters (Bower, 1926; Clausen, 1938, 1954; Nishida, 1957; Nozu, 1955). Based on the vascular anatomy of leaves, Chrysler (1945) and Nishida (1952) presumed *Botrychium sens. str.* to be the most primitive, and *Botrypus* (as *Osmundopteris*) and *Sceptridium* advanced. Another different opinion on the relationship was presented by Kato (1978a) utilizing sporangia as well as such foliar characters as basal sheath, and size and cutting of leaves. *Botrypus* (as subgenus *Osmundopteris*) was regarded as the most ancestral while *Japanobotrychium, Sceptridium* and *Botrychium sens. str.* as successively specialized.

The systematic position of *Helminthostachys* is also debatable. It is generally placed as an intermediate between *Botrychium sensu lato* and *Ophioglossum* (Clausen, 1938; Nishida, 1957). Nishida (1952) recognized a monotypic Helminthostachyaceae and a family Botrychiaceae in Botrychiineae. Kato (1982) suggested a closer affinity of *Helminthostachys* to *Japanobotrychium* and *Sceptridium* among the then recognized subgenera of *Botrychium.*

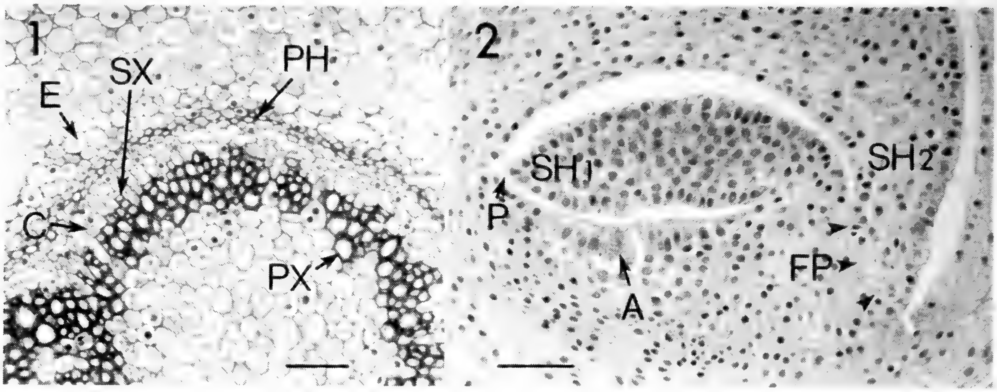
Since previous schemes of classification of Ophioglossaceae differ from each other, and none is widely accepted, the family needs re-examination from the viewpoint of phylogenetic classification. Because no closely related fossils have been found, such a systematic study must be based on comparative analysis of living genera and general paleobotanical information.

The best method of constructing a phylogenetic classification seems to me to be cladistics (e.g. Bremer and Wanntorp, 1978; Cracraft, 1974; Estabrook, 1978; Hennig, 1965, 1966; Nelson, 1974; Wagner, 1969; Wiley, 1980). In cladistics a phylogenetic classification is constructed by recognizing levels of monophyletic groups, which have synapomorphic characters derived from those of the nearest common ancestors. Monophyletic groups should be distinguished from paraphyletic (symplesiomorphic) and polyphyletic groups. Cladistics has since Hennig elaborated several different methods, each suitable for certain groups or subjects (Duncan and Stuessy, 1985; Funk and Stuessy, 1978). By adopting the basic method of cladistics (Hennig, 1965, 1966; Estabrook, 1978), an attempt is here made to examine the genealogical relationship in the Ophioglossaceae and arrange them in a phylogenetic classification. Basic monophyletic groups treated here are *Botrychium sens. str., Botrypus* (= *Osmundopteris*), *Helminthostachys, Japanobotrychium, Ophioglossum* and *Sceptridium,* although most of the genera need more detailed revisionary work.

## Phylogenetic Estimation of Characters

Almost all data on the characters analyzed here are cited from previous works. The basic source for this study is Kato and Sahashi (1977) and Kato (1978a, 1978b, 1982, 1983). The characters of each genus are presented in Table 1, and character state, primitive or plesiomorphic, vs. advanced or apomorphic, is estimated in each character.

Rhizome and stele. — The rhizome is radial in construction in *Botrychium, Botrypus, Japanobotrychium, Ophioglossum* and *Sceptridium.* It has been reported that *Sceptridium* (as *Botrychium sens. lat.*) *multifidum* has a spiral phyllotaxy of (1/3)2/5(3/8) (Stevenson, 1980), *Ophioglossum petiolatum* 2/5, *O. crotalophoroides* 1/2 (Webb, 1975, 1981), and *O. pendulum* 1/3 and 3/5 (Petry, 1914). The creeping



Plates 1 & 2. *Botrychium lunaria.* Pl. 1: Transection of rhizome. *C,* cambium; *E,* endodermis; *PH,* primary phloem; *PX,* primary xylem; *SX,* secondary xylem. Pl. 2: Longisection of shoot, showing pore closing at leaf sheath. *A,* shoot apex; *FP* with arrowheads, closed pore; *P,* pore; *SH1,* leaf sheath of first leaf primordium; *SH2,* leaf sheath of second leaf primordium. Scales 100 $\mu$.

rhizome of *Helminthostachys* is dorsiventral with two rows of leaves on the dorsal side (Farmer and Freeman, 1899). As is generally the case in vascular plants, the radial construction of rhizome in most genera of Ophioglossaceae is primitive while the dorsiventral rhizome of *Helminthostachys* is advanced.

The rhizomes of *Botrypus, Japanobotrychium* and *Sceptridium* have a cambium producing secondary vascular tissue. Although *Botrychium lunaria* has been described as having no vascular cambium (Nozu, 1956) or as having a cambium derived from the pericycle (Lang, 1913), it has the same organization as the others, excepting lower cambial activity (Takahashi, pers. commun.; Plate 1). There is no cambium in *Helminthostachys* and *Ophioglossum,* and Farmer and Freeman (1899) described the xylem as differentiating very slowly from the procambial strand in *Helminthostachys.* However, addition of xylem occurs both in *Helminthostachys* (Farmer and Freeman, 1899; Takahashi, pers. commun.) and *Ophioglossum* (Boodle, 1899). It is suggested that cambial activity has weakened and eventually disappeared, as in the evolutionary trend from a woody to herbaceous habit in Isoetales and related fossils (Rothwell and Ervin, 1985) and the flowering plants (Eames, 1961). The presence of a vascular cambium may be primitive and its absence advanced. *Helminthostachys* has a dorsiventral solenostele and *Ophioglossum* has a radial dictyostele, and this suggests a different or phylogenetically remote origin. It is interesting that Ophioglossaceae are similar to Isoetales (Lycopodiopsida) in possessing secondary tissue in very small (probably reduced) rhizomes.

Leaf sheath. — The stem apex and leaf primordia are covered by leaf sheaths to a varying extent depending on the genus (Clausen, 1938; Kato 1978a). The covering is incomplete in *Botrypus* in which sheath margins overlap along the entire length except at the base. In *Botrychium, Helminthostachys, Japanobotrychium* and *Sceptridium,* leaf sheaths cover more completely, and have a transversely elongate, small pore on the side opposite the leaf base, through which the inner cavity surrounding younger leaf primordia opens to the exterior. A further complete covering is seen in *Botrychium.* In *B. lunaria* the pore that exists in young leaf primordia disappears during leaf development (Plate 2; Kato, 1982). In *Ophioglossum* with a sunken stem apex, the pore is a narrow channel opening more or less obliquely (Holle, 1875; McAlpin, 1971). Closing of the pore takes place also in *O. termale* var. *nipponicum* (Imaichi, pers. commun.). In the light of the morphological basis that more appendicular structures are generalized, it is suggested that the

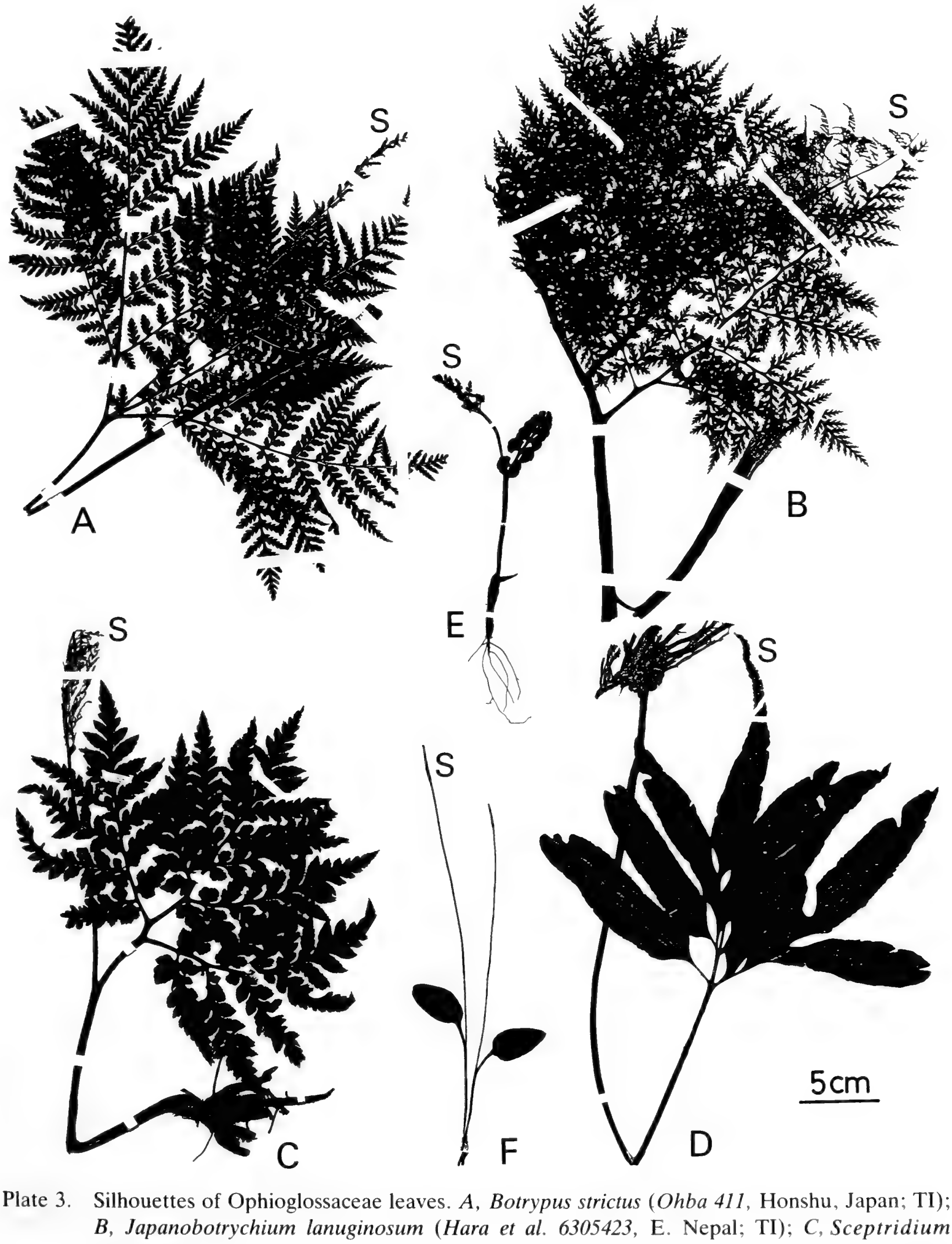


Plate 3. Silhouettes of Ophioglossaceae leaves. *A*, *Botrypus strictus* (*Ohba 411*, Honshu, Japan; TI); *B*, *Japanobotrychium lanuginosum* (*Hara et al. 6305423*, E. Nepal; TI); *C*, *Sceptridium daucifolium* (*Hara et al. 2458*, Darjeeling, Sikkim; TI); *D*, *Helminthostachys zeylanica* (*Tagawa & Iwatsuki 2170*, Ryukyus, Japan; TI); *E*, *Botrychium lunaria* (*Makino s.n.* 25 Jul. 1881, Mt. Fuji, Japan; TI); *F*, *Ophioglossum petiolatum* (*Yoshinaga s.n.* 19 Jun. 1938, Shikoku, Japan; TI); *S*, sporophyll.

incomplete covering of the leaf sheath in *Botrypus* is primitive and that of the other genera advanced. Among the latter, *Japanobotrychium*, *Sceptridium* and *Helminthostachys* are relatively primitive in this character, as compared with *Botrychium*, which has a further advanced leaf sheath.

Trophophyll morphology. — The trophophyll is variable in size and cutting in different genera, and variation in the two characters is more or less correlated (Plate 3; Clausen, 1938). *Botrypus* and *Japanobotrychium* have the largest and most dissected trophophylls in the Ophioglossaceae, and *Sceptridium* has smaller and less dissected trophophylls. The trophophyll of *Helminthostachys* is of almost the same size as that of *Sceptridium* but is much less dissected. The trophophylls of most *Botrychium* and *Ophioglossum* are the smallest, although in *Ophioglossum pendulum* they are exceptionally large (to 1 m long). They are simply pinnate in *Botrychium* while in *Ophioglossum* they are in general simple and entire, but often forked in *O. pendulum* and lobed in *O. palmatum.*

Except for *Ophioglossum pendulum* which might show some secondary leaf enlargement, Ophioglossaceae exhibit a continuous variation in leaf size and cutting between the larger and highly dissected trophophylls and the smaller and less dissected. Reduction and simplification, which is a general tendency in the lower vascular plants, is also conceivable in the Ophioglossaceae. This assumption is supported by an ontogenetic study by Imaichi and Nishida (1986) who showed apparently three-dimensional organization of trophophylls at early ontogenetic stages and the persistence of a tetrahedral apical cell at the apex of the primary through tertiary leaf axes in *Sceptridium ternatum.* It is also supported by an out-group criterion that the larger and finely dissected trophophylls are shared by *Japanobotrychium* and *Botrypus* which is an out-group for another group including the former genus, as indicated by sporangial morphology and other characters (see below). Therefore, *Sceptridium, Helminthostachys, Botrychium* and *Ophioglossum* have advanced trophophylls, compared to primitive ones in *Botrypus* and *Japanobotrychium.* Among the former, *Botrychium* has more advanced trophophylls and *Ophioglossum* has the most specialized.

*Helminthostachys* has a characteristic trophophyll: it is imparipinnate with oblong entire terminal and lateral pinnae, the basal and usually also the subbasal pinnae with conforming basiscopic pinnules. The presence of such basiscopic pinnules is shared with *Japanobotrychium, Sceptridium* and part of *Botrychium (B. lanceolatum).* Moreover, *Helminthostachys* and *Sceptridium* exhibit a strong similarity in leaf shape at the young ontogenetic stages: juvenile leaves of *Helminthostachys* with three deltoid-ovate leaflets (Fig. 1) are quite similar to those of *Sceptridium japonicum* (Nishida, 1955). It is presumed that the trophophyll of *Helminthostachys* has been derived from, or from a common ancestral form of, that of *Sceptridium* which at maturity is the most similar to *Helminthostachys* in leaf size and dissection.

Vascular branching in leaf axes. — Bower (1923) recognized two types of vascular branching in fern leaves; of those he regarded marginal branching as

Fig. 1. Leaves of very young *(left)* and young plants of *Helminthostachys zeylanica* (*Kato et al. C-8043*, Ceram, Indonesia; TI).

primitive and extra-marginal as advanced. The same evolutionary trend was applied to the Ophioglossaceae by Chrysler (1945), Nozu (1955) and Nishida (1957). Their arguments were based on an assumption that a simpler branching type is primitive and the more elaborate, advanced, and the three-dimensional archaic branching is maintained in a simpler form in vasculature in Ophioglossaceae leaves. Kato (1978b) made a detailed re-examination of leaves of the family and criticized the validity of such an assumption. He concluded that in the Ophioglossaceae simplification from extra-marginal branching to marginal might have taken place parallel to the leaf reduction and simplification discussed above. It is estimated that in vascular branching, *Botrychium* and *Ophioglossum* are derived and other genera primitive.

It is of little doubt that marginal and hetero-marginal branchings of the sporophyll vascular bundles are each related to extra-marginal, and the first two have no direct relationship to one another (Kato, 1978b). Based on the evolutionary trend in vasculature noted above and also the phylogenetic relationship discussed below that *Botrypus* and a group of the other genera are sister-groups, the hetero-marginal branching of *Helminthostachys* and the marginal one of *Botrychium* have been derived in parallel from extra-marginal by specialization, respectively.

Venation. — Veins are free in *Botrychium, Botrypus, Helminthostachys, Japanobotrychium* and *Sceptridium,* and anastomosing in *Ophioglossum.* Elaboration from free to anastomosing venation is a general evolutionary trend in megaphyllous leaves, although the reverse tendency seems to have taken place in occasional cases, e.g. Polypodiaceae, in relation to reduction in leaf size. In Ophioglossaceae, as in general in megaphyllous plants, the anastomosing venation in *Ophioglossum* with specialized simple leaves is believed advanced, and free venation in the other genera as primitive.

Among the free-veined genera, *Botrypus, Japanobotrychium* and *Sceptridium* have pinnate and forked venation in leaf segments, while veins in *Botrychium* are parallel, and lateral veins are parallel and occasionally anastomosing in *Helminthostachys* (Bhambie and Madan, 1982). Venation of the first three genera is primitive compared with that of the last two, being parallel to the above suggested evolutionary trend in trophophyll morphology.

Position of sporophyll on trophophyll. — The sporophyll is attached at or near the top of a stipe of the trophophyll in most genera, i.e. *Botrychium, Botrypus, Helminthostachys* and most species of *Ophioglossum.* In *O. pendulum* a sporophyll occurs on the lower part of the blade which is attenuated toward the short stipe, and in *O. palmatum* several sporophylls are attached near the blade margin. *Ophioglossum bergianum* also is aberrant in having a sporophyll at the stipe base. In *Japanobotrychium* the sporophyll occurs on the lower part of the trophophyll rachis. In most species of *Sceptridium* the sporophyll is attached on the lower part of the trophophyll stipe, and in *S. daucifolium* it is at the upper part of the stipe. Thus, that sporophylls occur at or near the top of the trophophyll stipe is a general and so probably primitive character state which exists in different genera with various leaf morphology. Comparatively, *Japanobotrychium,* some species of *Ophioglossum* and *Sceptridium* are apparently advanced. They are not considered a synapomorphic group of common origin, because the position of sporophylls differs in different genera, and each primitive stage is seen in most species in *Ophioglossum,* and in *S. daucifolium* in *Sceptridium.* In *Japanobotrychium* the vascular supply to the sporophyll actually branches below the branching point of vascular supplies to the trophophyll pinnae, thus indicating a close anatomical similarity to *Botrypus* with likewise extra-marginal vascular branching (Kato, 1978b).

Form and construction of sporophyll. — The Ophioglossaceae exhibit strong leaf dimorphism, sporophylls generally consisting of lamina-lacking leaf axes and sporangia, although abnormally, a lamina develops on sporophylls to some extent, or some sporangia are produced on trophophylls. The most extraordinary are the leaves with no trophophylls in *Botrychium paradoxum* (Wagner and Wagner 1981), *Ophioglossum kawamurae* (Tagawa, 1939), and *O. lineare* (Brause, 1912). Sporophylls are foliar, variously pinnate and more or less similar to trophophylls in *Botrychium, Botrypus, Japanobotrychium* and *Sceptridium,* while they are spikes in *Helminthostachys* and *Ophioglossum.* The former is a primitive character and the latter advanced. The last two are not considered synapomorphic, because they differ considerably in form and construction. In *Helminthostachys* the sporophyll is a spike consisting of a stipe and a rachis with sporangiophores along both sides. In *Ophioglossum* it is a simple spike which is considered to consist of a stipe and a narrow blade (not a rachis), because the sporophyll has an entire margin and anastomosing veins as the trophophyll, but with areoles in few rows, necessitated by its narrowness (Fig. 2).

The sporophylls are flattened, as are leaves in general, in all the genera of Ophioglossaceae but *Helminthostachys* in which they are cylindrical: the sporangiophores are arranged in two or three irregular rows along each side of the rachis (Kato, 1978a). In the family flattened leaves are primitive and cylindrical advanced. The sporangiophores are modified branches of leaf axes and vascular branching to the sporangiophores is extra-marginal, a character common to all genera except for *Botrychium* and *Ophioglossum* (Kato, 1978a).

Position and dehiscence of sporangia. — Phylogenetic comparisons among sporangia of the vascular plants and those of Ophioglossaceae have been made by Kato (1978a, 1982, 1983). This character is the most basic for reconstructing the phylogeny in this study, and the assumed evolutionary trend is in good accordance with paleobotanical evidence and comparative morphology of the extant groups. There are two types of sporangia, each in one of two phyletic lines in the early vascular plants and their descendants. In the megaphyllous group derived from the Rhyniopsida and Trimerophytopsida, sporangia are terminal at the end of axes or veins that have been derived from axes and dehisce longitudinally from the top to the base. In the microphyllous group including the Zosterophyllopsida, sporangia are attached laterally on axes or leaves (on the adaxial side) and dehisce distally along a transverse line.

In Ophioglossaceae, belonging to the megaphyllous group, sporangia terminal at the endings of leaf axes and with longitudinal dehiscence are primitive, while those apparently lateral on the side of leaf axes (but terminal at vein-endings) and with apparently distal dehiscence are advanced (Fig. 2). The former are present in *Botrypus* (particularly *B. strictus*) and the latter in the other genera. The sporangia of *Ophioglossum,* although quite the same in morphology as those of the latter genera, are unique in being sunken and embedded in lamina tissue along the margin of the spike which is a narrow blade, and not of an axial nature, as noted above (Fig. 2). Therefore *Ophioglossum* is in a further advanced character state in the position of sporangia. It is noteworthy that a similar evolutionary trend in sporangium morphology with reference to dehiscence is seen in the leptosporangiate ferns (e.g. Bower, 1935).

Suspensor. — It has been reported that the embryo of *Helminthostachys* and *Sceptridium* has a suspensor (Bierhorst, 1971; Lang, 1914; Lyon, 1905; Nishida, 1955; Nishida and Imaichi, 1971) while no suspensor is known in the other genera. A suspensor-bearing embryo is known in various vascular plant groups such as Lycopodiales, Selaginellales, Marattiales, gymnosperms and angiosperms which have a massive or compact gametophyte (Bower, 1908; Land, 1923; Lang, 1914). Such an embryo is generally regarded as primitive. Although there is no decisive evidence for the evolutionary trend in the suspensor of Ophioglossaceae,

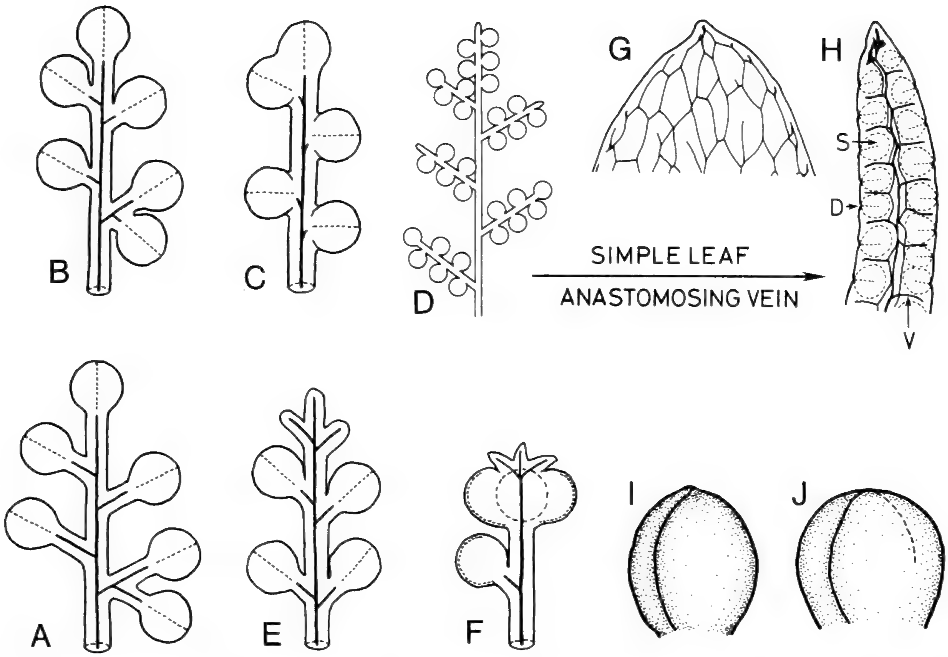


Fig. 2. Fructifications of Ophioglossaceae. *A*, presumed ancestral form; *B*, *Botrypus; C* & *D*, *Botrychium*, *Japanobotrychium* and *Sceptridium; E*, presumed ancestral form with distal sterile segments, equivalent to *B; F*, *Helminthostachys; G*, distal part of trophophyll of *Ophioglossum; H*, distal part of sporophyll of *Ophioglossum* (*D*, dehiscence line; *S*, sporangium; *V*, vein); *I*, *J*, sporangia; *I*, *Botrypus strictus; J*, *Botrychium*, *Japanobotrychium* and *Sceptridium*. (*A-C*, *E*, *F*, *I* & *J* after Kato (1978a)).

the cladogram presented below suggests the existence of a suspensor to be advanced, as far as information available at present is concerned. Another possibility is that the presence of a suspensor is ancestral in the family and this has disappeared in several genera, or that a suspensor-bearing embryo may be more widespread in the family than we know.

## Phylogenetic Relationship and Classification

The evolutionary trends of all the characters examined and a deduced phylogenetic relationship between genera of Ophioglossaceae are presented in Figure 3. All character phylogenies are compatible if only we assume that the presence of a suspensor in the embryos of *Helminthostachys* and *Sceptridium* is an advanced character state, based on its absence from *Botrypus* and *Japanobotrychium* both of which are out-groups of *Helminthostachys* and *Sceptridium*, and on the embryos of *Botrychium* and *Ophioglossum* lacking a suspensor. *Botrychium* and *Ophioglossum*, and *Helminthostachys* and *Sceptridium* are each synapomorphic groups which in turn constitute a higher level synapomorphic group with *Japanobotrychium*. Among the genera, *Botrypus* is the most primitive and *Ophioglossum* is the most advanced. *Japanobotrychium*, *Sceptridium* and *Helminthostachys*, and *Botrychium* are successively more advanced genera between the two extremes.

Each genus possesses its own unique advanced character(s), showing that it is an elaboration from its nearest ancestor. Exceptionally, *Botrypus* consistently shows the primitive state of all characters examined. However, *B. cicutaria* and *B. virginianus* are derived in their sporangial morphology and *B. strictus* in its spike-like narrow sporophyll. It is, therefore, obvious that *Botrypus* is also an elaboration

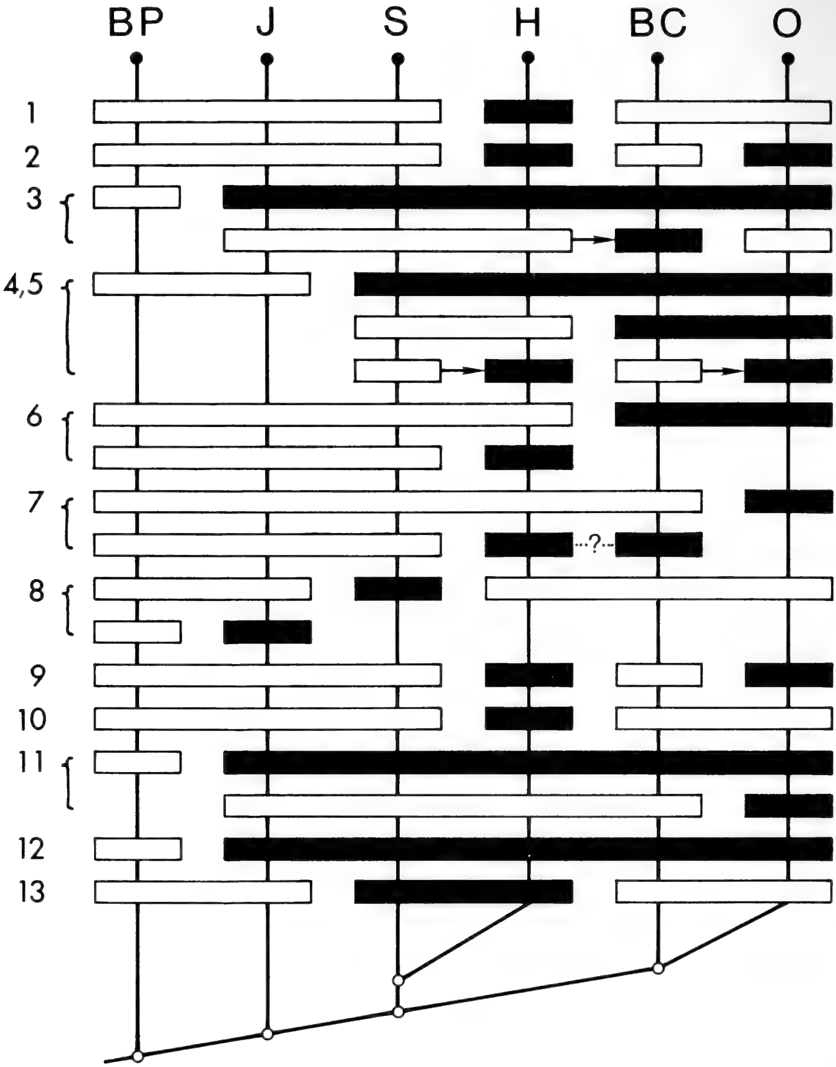


Fig. 3. Cladogram showing character state and phylogenetic relationship in Ophioglossaceae. Numbers at left side are character codes shown in Table 1. *White* and *black squares* indicate respectively primitive and advanced character states. *BP, Botrypus; J, Japanobotrychium; S, Sceptridium; H, Helminthostachys; BC, Botrychium; O, Ophioglossum.*

from the common ancestor, with its sister group being all the other extant genera of Ophioglossaceae.

The phylogenetic scheme presented in Figure 3 remarkably contradicts relationships postulated in currently accepted classifications. In these (e.g. Clausen, 1938; Nishida, 1952), *Botrychium, Botrypus, Japanobotrychium* and *Sceptridium* are united in a single group, i.e., genus *Botrychium sensu lato* or family Botrychiaceae. In the relationship obtained in this study it is not a monophyletic group and at most a paraphyletic or polyphyletic group.

For a comparison between the phylogenetic relationship of this study and that of Clausen (1938) and Nishida (1952) which differs from Clausen principally in rank of taxa, the divergence degree of the genera is estimated (Table 2). For each character, the primitive state is coded as 0 and the derived state as 0.3, 0.5, 0.7 or 1 according to the degree of deviation from the primitive state. All of the values are summed up as divergence degree. The phylogenetic relationship and divergence of

Table 2. Divergence of characters in Ophioglossaceae

| Genus | Character code* | | | | | | | | | | | | Divergence degree |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | |
| *Botrypus* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 |
| *Japanobotrychium* | 0 | 0 | 0.5 | 0 | 0 | 0 | 0 | 0.5 | 0 | 0 | 0.5 | 1 | 2.5 |
| *Sceptridium* | 0 | 0 | 0.5 | 0.5 | 0.3 | 0 | 0 | 1.0 | 0 | 0 | 0.5 | 1 | 3.8 |
| *Helminthostachys* | 1 | 1 | 0.5 | 0.5 | 0.7 | 0.5 | 0.3 | 0 | 0.5 | 1 | 0.5 | 1 | 7.5 |
| *Botrychium* | 0 | 0 | 1.0 | 1.0 | 0.7 | 1.0 | 0.3 | 0 | 0 | 0 | 0.5 | 1 | 5.5 |
| *Ophioglossum* | 0 | 1 | 0.5 | 1.0 | 1.0 | 1.0 | 1.0 | 0 | 1.0 | 0 | 1.0 | 1 | 8.5 |

* Following Table 1 (13 excluded).

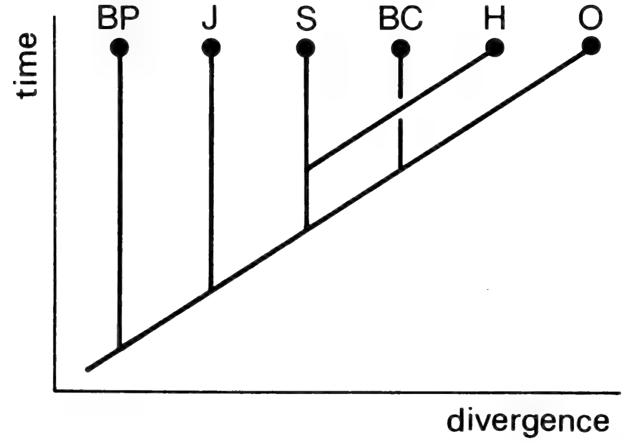


Fig. 4. Phylogenetic relationship and divergence of characters in Ophioglossaceae. *BP, Botrypus; J, Japanobotrychium; S, Sceptridium; BC, Botrychium; H, Helminthostachys; O, Ophioglossum.*

characters are shown in Figure 4. From this estimation of divergence, it is clear that *Helminthostachys* and *Ophioglossum* are the most specialized genera while *Botrychium, Botrypus, Japanobotrychium* and *Sceptridium* maintain relatively generalized characters. In the previous classifications, the former highly specialized groups have been treated as independent genera, while the latter relatively primitive genera have been classified into a single, artificial, non-monophyletic group (*Botrychium sensu lato* or Botrychiaceae).

As regards the phylogenetic classification of Ophioglossaceae, I admit that the pair of the most closely related genera, *Botrychium* and *Ophioglossum,* and *Helminthostachys* and *Sceptridium,* are distinct enough to warrant generic status, and therefore the others also deserve generic or higher rank. Although some authors (e.g. Nishida, 1952) recognize as genera *Cheiroglossa, Ophioderma* and *Rhizoglossum* as well as *Ophioglossum,* these share advanced characters as shown in Table 1 and Figure 3, so that they are best treated as infrageneric taxa. It is not feasible to classify the family into subgroups in any way although the most meaningful two groups would be *Botrypus* and then another group consisting of all the other genera. In conclusion, I propose the following classification:

### Family Ophioglossaceae

1. Genus *Botrypus*
2. Genus *Japanobotrychium*
3-1. Genus *Sceptridium*
3-2. Genus *Helminthostachys*
4. Genus *Botrychium*
5. Genus *Ophioglossum*

In this scheme the genera are arranged in sequence as to reflect the phylogeny shown in Figures 3 and 4, using Cracraft's (1974) sequencing classification method. In this classification the following relationship is indicated: 1—2—3 (1—2)—4—5, and genus 1 is the most primitive and 5 the most advanced.

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# The Herbarium and Arboretum of the Forest Research Institute of Malaysia at Kepong — a Historical Perspective

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### Abstract

The beginnings of the Herbarium and Arboretum of the Forest Research Institute of Malaysia at Kepong are documented, as are the roles of the people associated with these events and developments from British colonial times until Malayanisation in the 1960s. The Herbarium was founded by Alfred M. Burn-Murdoch, the first Chief Forest Officer of the Straits Settlements and Federated Malay States, in 1908. The Arboretum was begun in 1928-29, with James Watson (Forest Economist) and Frederick Foxworthy (Forest Research Officer) playing significant roles in its establishment. The influence of the government of the Straits Settlements and Federated Malay States and the roles of Burn-Murdoch, Foxworthy, Watson, Symington and Wyatt-Smith, likewise of their colleagues and associates, in the development of botanical studies in Malaya are traced from the beginning of the 20th Century, through military occupation during the Second World War, until the 1960s.

## Prologue

Early notions of placing the guardianship of the forests of the Malay Peninsula under a more systematic arrangement may be traced to the time of the Straits Settlements, a British Crown Colony consisting of Malacca, Penang, Province Wellesley, Singapore, Pangkor and the Sembilan Islands. It was in 1879 that the Colonial Engineer of the Straits Settlements, Major J.F.A. McNair, provided the earliest record of forestry in a report that supplied descriptions of the main timber trees and which recommended the formation of a forest department. It was not until 1883 that a small department of forests in Singapore was created under the Superintendent of Gardens, Straits Settlements, which position was held by Nathaniel Cantley from 1880 until his death in 1888.

In 1895, when the states of Perak, Selangor, Negri Sembilan and Pahang formed the Federated Malay States (each of which had a British Resident), the control of forests in the Straits Settlements was transferred from the Director of Gardens to the State Land Officers, as was the practice in the Federated Malay States. Henry Nicholas Ridley (who succeeded Cantley), pointed out that this was not a satisfactory arrangement for looking after all matters pertaining to forests. In a report on the forests of Selangor in 1896 he thus recommended the establishment of a forest department for the Federated Malay States (Mead 1936; Watson 1950). H.C. Hill, commissioned in 1900 from the Indian Forest Service to report on forest administration in the Straits Settlements and Federated Malay States, recommended the appointment of a Chief Forest Officer to take charge of forests (Hill 1900a, 1900b). This resulted in the transfer of Alfred M. Burn-Murdoch from the Burma Forest Service in 1901 to the post of Chief Forest Officer of the Straits Settlements and Federated Malay States.

## The Beginnings of the Herbarium

Burn-Murdoch had, from 1901 (the year he arrived in Malaya) until his death in Klang in 1914 (Anon. 1914), recognised the relevance of producing an account of commercially important timber tree species of the Malay Peninsula. It was, therefore, of direct concern to him to obtain first-hand knowledge of forest trees, and so he developed an interest in collecting plants as reference material. His earliest documented plant collections in Malaya date from 1903 (van Steenis-Kruseman 1950). From 1904, Burn-Murdoch's office was known as the Conservator of Forests, Straits Settlements and Federated Malay States. Burn-Murdoch (1909) recorded in the 1908 Annual Report of the Forest Department that "during the year, a collector of specimens was employed by the Conservator, who collected many herbarium specimens of forest trees ... submitted to Mr. Ridley ... for identification ..." and that "... a collection of the named specimens was commenced and ... kept in the office of the Conservator for ... reference."

In 1908, therefore, the Forest Department started a managed collection of pressed plant specimens that was to develop into the present herbarium of the Forest Research Institute of Malaysia at Kepong. Burn-Murdoch, the man who founded this herbarium, had himself travelled extensively in the field collecting plants in all states of present-day Peninsular Malaysia except Perlis, Kedah, Trengganu and Kelantan (Burkill 1915; van Steenis-Kruseman 1950). He distributed some of his collections to the herbaria of the Singapore Botanic Gardens and the Royal Botanic Gardens, Kew.

Burn-Murdoch was a person of tremendous energy; it is to his credit that the first reserved mangrove swamp forests were established for Perak and Selangor. His book, *Trees and Timbers of the Malay Peninsula* (Burn-Murdoch 1911, 1912), is the forerunner of forestry publications that form the series of Malayan Forest Records. Despite his primary interest in forest trees, Burn-Murdoch's collections encompassed other groups of plants, including shrubs, lianes, palms, parasites, saprophytes, ferns and aquatic herbs (Burkill 1915), a testimony to his wide interest in natural history.

At the beginning of 1915, the year following that of his death, the Forest Department herbarium consisted of 481 numbers, representing about 370 species (Foxworthy 1918), collected by both British serving officers as well as local forestry staff (many of these collectors were forest rangers) and accommodated in a single small cupboard at the Forest Department premises in the Supreme Court building on Court Hill in Kuala Lumpur. Under Burn-Murdoch's successor, G.E.S. Cubitt, accessions to this collection (often referred to as the "local herbarium" in departmental reports) continued, albeit slowly, and by early 1916 there were 500 numbers representing about 385 species (Foxworthy 1918). In 1916, the Wray herbarium of the Agriculture Department was transferred to the Forest Department in Kuala Lumpur (Cubitt 1919).

With the potential of forest resources and a rubber-dominated agriculture in Malaya becoming increasingly recognised, the scenario of the time saw a gradual de-emphasis of agri-horticultural and forestry organization in Singapore, where the Botanic Gardens had served the agro-economic development of the Straits Settlements since 1875, and its centralization in Kuala Lumpur, the administrative centre of the Federated Malay States (Furtado & Holttum 1960; Burkill 1983). In 1918, a desire was already crystallizing to intensify botanical research based in Kuala Lumpur where was housed the headquarters of the Department of Forests, Straits Settlements and Federated Malay States, and the Department of Agriculture, Federated Malay States. This was the year in which Cubitt secured the services of Frederick William Foxworthy as the first Forest Research Officer of the Federated Malay States and Straits Settlements, after which the size of the Forest Department's "local herbarium" was substantially increased. Very much a botanist, Foxworthy, upon his arrival in Malaya, spent a great deal of time acquainting himself with the local flora and vegetation, and rearranging both the Wray herbarium (maintained separately) and the "local herbarium," identifying, labelling and recording a large amount of old and newly collected material (Cubitt 1919). Foxworthy had the assistance of I.H. Burkill in identification, and both Burkill and C.F. Baker, of the Singapore Botanic Gardens, together with Foxworthy and several Forest Department staff members, became the main contributors to this collection (Cubitt 1919). Foxworthy also distributed duplicates of plant collections to Singapore and Kew (Cubitt 1919), from what was now called the Forest Herbarium, housed in the same premises at Kuala Lumpur's Court Hill.

Also in 1918, the Governor of the Straits Settlements (S.S.), Sir Arthur Young, who was also the High Commissioner to the Federated Malay States (F.M.S.), expressed to the Secretary of State for the Colonies the desirability of maintaining work in systematic and economic botany outside the proposed joint S.S. & F.M.S. Department of Agriculture. By December, 1923, a forestry committee formed by Cubitt had met with A.S. Haynes, Secretary for Agriculture, S.S. & F.M.S., and I.H. Burkill, Director of Botanic Gardens, S.S., to discuss the centralization of botanical work in Malaya. They decided that the Singapore Herbarium, as well as work in systematic and economic botany carried out by the Singapore Botanic Gardens and the F.M.S. Museums Department, should be transferred to the premises of a new Botanical Department to be established in Kuala Lumpur. Furthermore, the Public Gardens in Kuala Lumpur was to be developed as a botanic garden, and the Penang and Singapore gardens were to function as branches. These plans, as explained by Burkill (1983) in some detail, were not translated into reality. The rubber slump of 1924 affected revenue adversely and Sir Lawrence Guillemard, then Governor/High Commissioner, did not overrule strong opposition from Sir George Maxwell, Chief Secretary to the F.M.S., against effecting the centralization of botanical research. Although Maxwell finally agreed, just before his retirement in 1926, to the establishment of a new department (to be known as Botanical Survey, Malaya) the S.S.–F.M.S. Government appears to have lacked any further impetus towards realizing these objectives. In 1926, the Wray herbarium, hitherto curated in the Forest Herbarium at Kuala Lumpur, was incorporated into the Singapore Herbarium (I.H. Burkill 1927; van Steenis-Kruseman 1950). H.M. Burkill (1983) records —

> "In 1929, the world was perceptively sliding into another slump ... the Singapore Botanic Gardens continued to provide the botanical service Malaya needed. The Forest Department was particularly affected since a major aspect of tropical forestry is to be able to make reliable inventories of forest species. Failure to bring the resources of the Singapore Herbarium to Kuala Lumpur led to the setting up of specialist facilities within the Forest Research Institute, Kepong ..."

Under Foxworthy, the Forest Herbarium developed rapidly. By the end of 1919, the herbarium (excluding the Wray collection) contained some 5000 numbers representing 1700 species, of which about 1200 were trees (Cubitt 1920), and at the close of 1920, this had increased to 6000 numbers representing about 2100 species of which about 1600 were trees (Barnard 1921). Although Foxworthy is primarily remembered for his role in organizing the beginnings of forestry research in Malaya, his account of *The Commercial Woods of the Malay Peninsula* (Foxworthy 1921) is the first comprehensive work summarizing the botany of Malayan dipterocarps in a form suited to foresters. This publication began the Malayan Forest Records as its first number; his *Dipterocarpaceae of the Malay Peninsula*, issued as No. 10 of the same series (Foxworthy 1932), was the first plant systematic monograph produced at the newly established Forest Research Institute. It incorporated the results of contemporary revisionary work and set the stage for a more comprehensive treatment of this important timber family. Foxworthy had been a botanist with the Bureau of Science in Manila and held the same breadth of vision as Burn-Murdoch in the attention he gave to plant groups of lesser commercial

Plate 1. F.W. Foxworthy (1877-1950), the first Forest Research Officer of the Federated Malay States and Straits Settlements. His *Dipterocarpaceae of the Malay Peninsula,* published in 1932, was the first plant systematic monograph produced at the then newly established Forest Research Institute at Kepong.

importance. His account of *Minor Forest Products of the Malay Peninsula* (Foxworthy 1922) testifies to this, and in his annual report for 1923 (Foxworthy 1924) he noted: "The most serious lack about our herbarium at present is room ... the condition has become very acute with the beginning of our collection of rattans." In 1926, a number of bamboo specimens were identified by the specialist J.S. Gamble at Kew (Foxworthy 1927).

With Foxworthy as Forest Research Officer, the Forest Research Institute (FRI) was first functionally established at its present site at Kepong in 1926, when a forest nursery and several experimental plantations were begun. Although the decision to set up the FRI was first taken in 1921 it was not until August 1925 that the Regent of Selangor was approached to approve 800 acres at Kepong for the purpose, and only in 1929 was the main office building constructed (Anon. 1950b; Watson 1950; Menon 1969), and the Forest Herbarium moved from its original site to a room on the upper floor of the east wing of this building (Foxworthy 1930). The following year, Foxworthy noted (Foxworthy 1931) that "... the herbarium now contains material of about 70 percent of the known tree species of the Peninsula; ..." this was based on his earlier estimate (Foxworthy 1918) of about 2200 species of trees recorded from the Peninsula. During this formative period of the herbarium, in the latter years of the 1920s, there was a continuing spirit of cooperation between the Singapore Botanic Gardens and the F.M.S. Forest Department. Apart from the assistance of botanists based at Singapore, the Forest Department had also enlisted, in several assignments, the help of Mohamed Nur bin Mohamed Ghous, the Herbarium and Museum Assistant of the Singapore Botanic Gardens. Mohamed Nur was prominent among collectors who had accompanied Foxworthy in the field (Burkill 1958). Foxworthy retired in 1932, after which the post of Forest Research Officer was abolished and replaced by a conservatorship.

## Watson and the Kepong Arboretum

The last years of the 1920s were significant in another respect. As the Forest Research Institute settled down in its new premises at Kepong, it was recognized that botanical and forestry research required the support of carefully planned living plant collections. Even though experimental tree plantations at Kepong were initiated in 1926, Foxworthy looked forward to the eventual specialised collections. In a memorandum to the Forest Economist, James Gilbert Watson (No. 3 in F.R.O. 189/27 dated 20th October 1927), Foxworthy wrote of palms: "A special place might be set aside for a collection of the tall growing palms. Fairly good soil will be needed and the plants should be set far enough apart to give them a chance to spread ..." In effect this must have been carried out, although there is no traceable record on where the "palm site" was; the oldest palm specimens to be found in the arboretum records are a Bayas *(Oncosperma horridum)* and a Nibong *(O. tigillarium)* planted much later in 1953, and today still standing side by side at the intersection of Arboretum Road with the Sungei (River) Kroh.

James Watson (son of William Watson, once Curator of the Royal Botanic Gardens, Kew) had had some practical experience at Kew as well as at Berlin when he studied forestry at Eberswalde in Germany. He joined the Forest Department in Malaya in 1913 as a Forest Officer and eventually succeeded Foxworthy to lead the Forest Research Institute in 1932. His *Malayan Plant Names* (Watson 1928a) and *Mangrove Forests of the Malay Peninsula* (Watson 1928b) had just appeared as Malayan Forest Records No. 5 and 6, respectively. In a note (No. 3 in F.E. 93/27 dated 23rd September, 1928) to Foxworthy, Watson volunteered to begin establishment of an arboretum:

> "I should very much like the formation and care of this part of the Kepong scheme to be included in my duties on my return from leave, more particularly in view of my past experience in this class of work, and from the fact that I should be living in the middle of the area that it is proposed to dedicate to the purpose. I discussed the matter on several occasions with the Conservator (Mr. Cubitt) who is, I believe, substantially in favour of the principle on which I wish to work, and who pointed out the desirability of a representative collection in view of the impending transfer of botanical research from Singapore to K. Lumpur. When we discussed the subject a short time ago, I do not think that we were regarding it from the same angle. I should like, therefore, to present the case as it appears to me ...

Plate 2. J.G. Watson (1889-1950), Conservator in charge of the Research Branch of the Malayan Forest Service during 1932-1936. He was responsible for the establishment of the Arboretum of the Forest Research Institute at Kepong in 1929, when he was Forest Economist.

"My idea of an arboretum is essentially a well-grown and representative collection of trees ... maintained for purposes of reference and as a convenient source of seeds and herbarium material for exchange ... In other words, it is primarily a living herbarium and, as such, it should be arranged as systematically as is practicable.

"It is clearly impossible to provide the trees in such a collection with the conditions that they will meet with in nature, for it may be assumed that each has its peculiar optimum which is not likely to be found in open country covered with lalang *[Imperata cylindrica]*, following exhaustion of the soil from root-crops, exposure, and the cumulative effects of Chinese vegetable gardening. Further, the wide spacing that must be adopted to allow the trees to develop, precludes any mutual shelter or natural enrichment of the soil for many years to come. It will be necessary ... to give them more attention than it is practicable or desirable to give to forest plantations.

> "The growth of individual trees in an arboretum cannot be expected to provide data of much silvicultural value, though (particularly in the case of exotics) it may provide useful preliminary indications and forestall needless expenditure on ... species that are foredoomed to failure through unsuitability of climate ...
>
> "Apart from its scientific values, an arboretum at Kepong will serve a very useful purpose in the way of advertisement and propaganda, for with it we can demonstrate our ability to grow trees at a price, and thereby emphasize the difficulties with which we are faced in the field. And, finally, there is the aesthetic aspect to be considered, and the desirability of ... encouraging the rapid and healthy growth of trees in the neighbourhood of the office and residential portions of the reserve ...
>
> "It will not be possible to adopt a systematic grouping according to families (as I originally suggested) as supplies are likely to be too irregular ... but I suggest that one third of the area be definitely dedicated to the dipterocarps, and a small portion to exotics ... Belukar [secondary forest] forms, and trees that are commonly found and are easily accessible elsewhere at Kepong, will not ordinarily be planted, though they may be retained if they happen to be growing in the arboretum area. Generally speaking ... the commercial trees will take precedence if space is at all cramped ...
>
> "But as ... it is not likely that funds will be available for planting this year ... I suggest, therefore, that the available seedlings in the nursery should be earmarked and listed, and that we content ourselves this year with marking out their positions in the field in order that planting may start at once in 1929."

In the ensuing years following establishment of the dipterocarp and non-dipterocarp sections of the Arboretum, departmental correspondence indicates an active pursuit of this goal by both Watson and Foxworthy. These two sections were to mature, many years later, into the two largest collections at Kepong, the dipterocarp collection being the finest in the world.

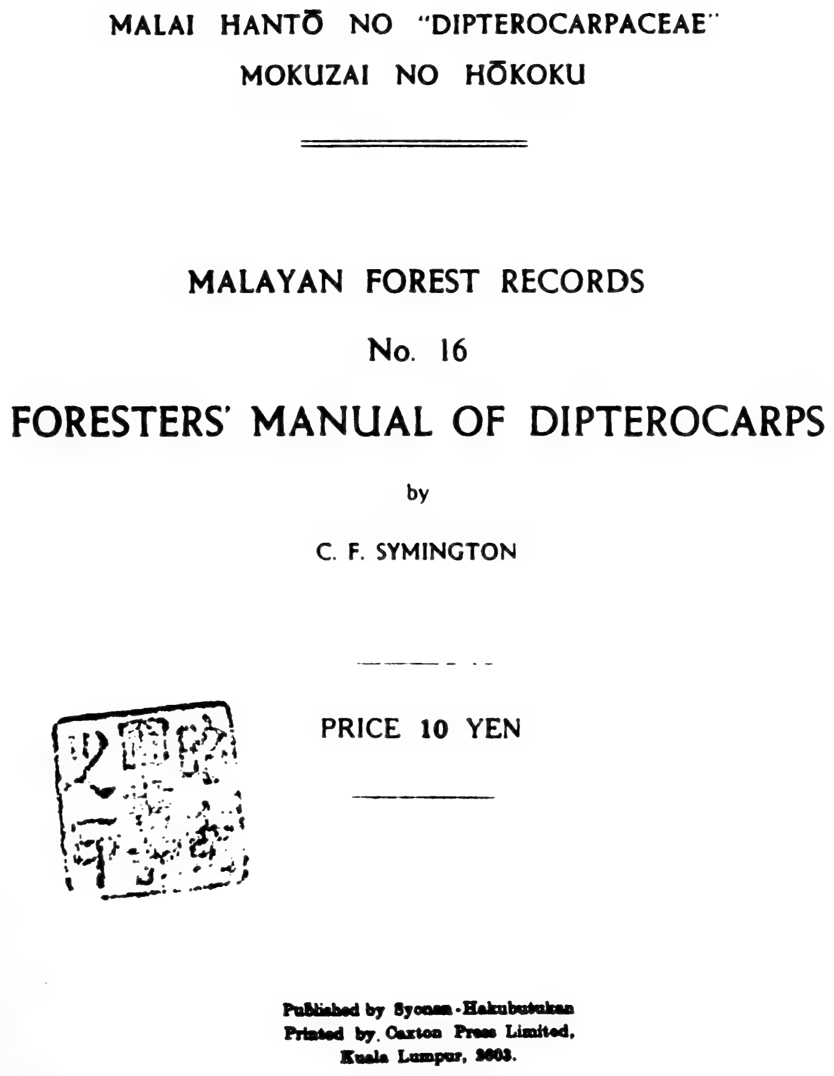
## Symington

In 1929 Colin Fraser Symington joined the FRI (Forest Research Institute) as Assistant Conservator of Forests and began to assist in the running of the herbarium; in 1934 he was designated the first Forest Botanist. Symington had envisioned, in 1936, producing a foresters' tree manual comprising all the Malayan timber-producing families. However, it was obvious that much research in systematic botany was still required and that a great amount of instability still existed in the botanical nomenclature. He concentrated on, and became the authority on the Dipterocarpaceae, the most important timber-tree family in Malaya and SE. Asia.

Symington completed his *Foresters' Manual of Dipterocarps* (No. 16 of the Malayan Forest Records) at Kepong in 1940. In November, 1941, typesetting of the book had begun at the Caxton Press in Kuala Lumpur but by the following month, both Symington and the manager of the press were forced to retreat to Singapore in the face of the Japanese invasion. In January 1942, Symington with his family boarded a ship for Australia (Corner 1981). At Singapore, E.J.H. Corner, Assistant Director of the Singapore Botanic Gardens, learnt from Mrs. Symington that the typescript had been left with the printer in Kuala Lumpur, but he was not successful in persuading Symington to leave a second copy at the Singapore Herbarium. Symington's important work on the Dipterocarpaceae would have been lost during the War, were it not for the timely initiative of Corner (then confined with other staff members to the Gardens), who informed Hidezo Tanakadate, then acting Director of Raffles Museum in occupied Singapore, of the typescript left in Kuala Lumpur. Tanakadate, a professor at the Tohoku Imperial University of Sendai, understood the value of Symington's work and intervened in a similarly timely manner. He obtained the release of H.E. Desch (who had worked closely with Symington at Kepong, and was author of *The Timbers of the Dipterocarpaceae,* No. 14 of the Malayan Forest Records) from the Changi Military Camp. Tanakadate and Desch travelled to Kuala Lumpur to find the galley proofs of the manual kept partly at the Caxton Press by L.E. Labrooy (Desch 1962) and partly at the FRI, Kepong (Tanakadate 1943). The proofs were corrected by Desch

Plate 3. C.F. Symington (1905-1943), designated the first Forest Botanist in the Forest Research Institute at Kepong in 1934. He was forced to flee Malaya in 1942 in the advent of war, and died in Nigeria the following year.

in Singapore at the Museum and the Changi PoW Camp, and the botanical names were scrutinised by Corner in the Gardens. The cost of printing 500 copies of Symington's manual (Symington 1943), at the Caxton Press in Kuala Lumpur, was met personally by Tanakadate and the Marquis Yositika Tokugawa, then acting President of the Raffles Museum and Library (Corner 1946). The book appeared under the Japanese title of *Malai Hanto no "Dipterocarpaceae" Mokuzai no Hokoku,* and was priced at 10 yen.



MALAI HANTŌ NO "DIPTEROCARPACEAE"
MOKUZAI NO HŌKOKU

MALAYAN FOREST RECORDS

No. 16

FORESTERS' MANUAL OF DIPTEROCARPS

by

C. F. SYMINGTON

PRICE 10 YEN

Published by Syonan-Hakubutukan
Printed by. Caxton Press Limited,
Kuala Lumpur, 2603.

Plate 4. The cover of the original issue of Symington's *Foresters' Manual of Dipterocarps,* issued by the Japanese Administration in Singapore in 1943.

It is a credit to the scientific community that men like Tanakadate could in time of war and hostility write: "scientific literature should not be obstructed by war" (Tanakadate 1943). In spite of Symington's departure from occupied Malaya, and the events that led to the publication of his book, the FRI was never to have back the botanist whose monograph of the Dipterocarpaceae was to become one of the best known works in Malayan botany. Symington returned to England and was posted to the forestry service in Nigeria where, in desperation, he took his own life in 1943, unaware of the fate of his book.

## The War Years at the Ringyo Shikenjyo

After war broke out on 8th December, 1941, there were no resident British officers in charge at the Forest Research Institute, which the Japanese called the "Ringyo Shikenjyo" (Forestry Experimental Station). V.L. Bain, by virtue of being Eurasian, was exempted from detention and appointed the acting State Forest Officer for Selangor by the Japanese Military Administration. Bain was able to reappoint several local staff members at Kepong in 1942. Aziz bin Budin, Technical Assistant to the Herbarium, reappointed in April 1942, was put in charge of the Botanical Division of the Institute. Aziz reported for 1942 —

> "During the former regime 78 herbarium cases were filled with herbarium sheets ... The looters have done considerable damage to this section. They removed almost all the cases, throwing all the valuable specimens on the floor. Some sheets were also taken away ... The herbarium, a room of 33 ft by 50 ft, was completely filled with mounted herbarium sheets filled to a foot depth. In addition to this the looters removed four copper heads of the laboratory taps, thus letting water to overflow the room. The result was that most of the herbarium sheets were soaked completely ... Those sheets which were beyond salvage, were discarded ...
>
> "It is estimated that about ⅔ of the original specimens of 43,000 sheets will be saved ..."

The plundering of the herbarium by looters was a grim prologue to the uncontrolled felling of forests for timber and food-growing that was beginning during those war years.

In September 1942, Yukio Tsuji was despatched by the Japanese Military Administration in Malaya to serve as the Chief Research Officer of the Forest Research Institute at Kepong. Tsuji graduated from the Department of Forestry of Tokyo University in 1919 and had been a research officer in the Japanese Government Forest Experiment Station (known as the Forestry and Forest Products Research Institute since 1958) before his appointment in Malaya. He remained in charge of the Forest Research Institute at Kepong until the end of the War.

In his programme of reorganization of the herbarium, Aziz wrote —

> "All strewn herbarium sheets comprising nearly 30,000 in all to be critically examined, identification supplied from herbarium registers and finally to be distributed to their various family group. Each family is further to be ... rearranged into genus and species alphabetically ... kept in the herbarium cases, at present 24 cases in all ... all salvaged sheets to be dried individually ... Naphthalene flakes or Paradichlor benzene to be kept in the cases ... If index cards are available each herbarium sheet is to be indexed."

Aziz noted that "missing sheets [were] to be replaced either by duplicates or by new collection" and in fact during the year made collecting trips to Sungei Buloh, Bukit Bruang, Bukit Lanjan and the Central Experimental Station at Serdang, with the assistance of Forest Guards Sow bin Tandang and Tachun bin Baba, who were reengaged in August. Sow had worked the previous twelve years together with Symington. Aziz's report for 1943 seemed less desperate:

> "Identifications were supplied to the Forest Department, majority of the requests were to identify some of the Commercial Timber-trees of Malai [Malaya] ... Routine identifications ... has taken up a disproportionate portion of the Technical Assistant's time ...

> "Some 46 mounted duplicates were sent to the State Forest Officer, Kelantan, as a guide to the identification of trees ... Some specimens were also ... forwarded to the Navy Department, Syonan-to [Singapore] ...
>
> "The Technical Assistant together with one of the collectors accompanied the Director of Forestry, on his inspection tour of Klang, where swamp jungle was studied.
>
> "Acquisition of herbarium material during the year totalled 312 ... The figure seemed very small indeed as compared to the past years ..."
>
> "Several Nippon Officers visited the Herbarium during the year — and some have spent good time in studying plants of commercial utility."

The visiting Nippon officers referred to in Aziz's report included Professor Ryujiro Ishida, who was despatched to survey research organisations in Malaya in 1943. Together with another officer named Utsuki, Ishida visited the Forest Research Institute at Kepong on 17 April 1943. He subsequently wrote a report on 14 organisations he visited, including the Wood Technology Laboratory in Kuala Lumpur and the Rubber Research Institute.

Watson, who succeeded Foxworthy as Conservator in charge of the Research Branch of the Malayan Forest Service in 1932, and later, J.P. Mead as Adviser on Forestry in October 1940 had retreated to Singapore with the advent of war and was interned when Singapore fell on February 15th, 1942 to Japanese hands. He was to spend three and a half years as internee, first at Changi Prison and then at Sime Road (Anon. 1950a). Most of the remaining officers of the Forest Service who had not left Singapore were also interned or were prisoners-of-war, until the surrender of the Japanese on August 15th, 1945. Bain, as acting State Forest Officer for Selangor, had appointed J.S. Wijasuriya as the Chief Clerk of the Forest Research Institute, who took charge of the Institute during this dismal period since 28th July, 1942. Thus, Wijasuriya, together with Technical Assistants P.K. Balan Menon and Aziz Budin, both reengaged along with 3 clerks and a skeleton team of subordinate field staff and labourers, went about the business of reorganizing and maintaining the facilities and work as best as possible under the clouds of war.

By the end of the War, the area under experimental plantations on the Institute's premises was reduced from 494 to 377 acres. Of a total of 363 trees in the arboretum, 97 were felled or damaged irreparably by fire.

## From War to Malayanisation

There was no hiatus following the cessation of war in Malaya in the August of 1945. Reassessment and rebuilding had to begin. Watson returned to serve as Forestry Adviser to the Colonial Office during 1946-47 before retiring (Anon. 1950a) and F.H. Landon was placed in charge of the Institute from 1946 to 1948 (Menon 1969). The herbarium came under the charge of John Wyatt-Smith, who served as Forest Botanist between November 1946 and May 1955. The Forest Herbarium at Oxford University returned to Kepong herbarium, as a gift, its duplicate material of specimens from the Kepong collection that were lost in the war. Field collection of specimens regained momentum. In 1949 the herbarium was rearranged (Anon. 1950c) according to the classification of Bentham & Hooker's *Genera Plantarum;* this system has been retained as the basic framework of classification since then. With the publication of *Index Herbariorum* in 1952 (Lanjouw & Stafleu 1952), the FRI herbarium, Kepong, adopted KEP as its acronym.

Although in full realization that a companion volume to Symington's Dipterocarp Manual was essential, in that similar information on timber trees of other families were needed, Wyatt-Smith was aware that the state of knowledge and systematy of these other plant families could only be advanced gradually. He thus produced a series of illustrated notes on the Burseraceae, Leguminosae, Myristicaceae, Sapotaceae, Lauraceae and Sapindaceae (Wyatt-Smith, 1953-54) that could

Plate 5. J. Wyatt-Smith (b. 1917), Forest Botanist at the Forest Research Institute at Kepong during 1946-1955, was later Forest Ecologist and Forest Silviculturist for some years.

serve as preliminary accounts and simultaneously would be of practical use to foresters. Wyatt-Smith also worked with M.R. Henderson, then Director of the Singapore Botanic Gardens, on revising the difficult genus *Calophyllum* for Malaya (Henderson & Wyatt-Smith 1956). Such efforts, however, were interrupted.

Wyatt-Smith's tenure as a forest botanist in the widest sense of the term saw him first as Forest Botanist (November 1946 — May 1955, since 1951 as Forest Botanist and Ecologist), then after a period of leave as Forest Ecologist (Botany) (September 1958 — 1959) and subsequently as Forest Silviculturist (1959 — April 1963). The nature of these various posts reflected a renewed emphasis on silvicultural research and practices. Between 1950 and 1954, Wyatt-Smith and R.C. Barnard (the latter then Silviculturist) were put mainly in charge of producing a contemporary manual of silviculture which was the first priority of the Silvicultural Division. Although Barnard had published a preliminary treatment of the main scope of silvicultural work (Barnard 1954), he retired in 1956 by which time Wyatt-Smith had been transferred on field duty to Kedah as its State Forest Officer. In 1957, G.G.K. Setten, then Chief Research Officer, petitioned for the return of Wyatt-Smith to complete the manual of non-dipterocarps and of J.E. Cousens, formerly Instructor of the Forest School at Kepong, to complete the manual of silviculture. But Cousens left the Forestry Service in 1958 and circumstances dictated the transfer of Wyatt-Smith from botany to silviculture (Mohammed Alwy, foreword in Wyatt-Smith 1963).

If botanical work towards the non-dipterocarp manual of timber trees was interrupted by these circumstances, it also amply displayed the relevant association between forest botany, ecology and silviculture. With broad perceptions accruing from much field experience in these areas, Wyatt-Smith published the bulk of the work in his manual of silviculture (Wyatt-Smith 1963). His ecological research plots at Bukit Lagong and Sungei Menyala, set up in 1947, were to become, decades later, among the oldest study plots in the tropical world.

With the approach of the formation of the Federation of Malaya and thereafter the Federation of Malaysia in 1962, the transition towards Malayanisation came into being. Kizhakkedathu Mathai Kochummen, working with Wyatt-Smith as Research Assistant from January 1953 to May 1955, and Assistant Botanist from June 1955 to June 1971, took sole charge of the herbarium during 1960-63. The targetted deadline for Malayanisation of the Research Branch was 1965. In 1963, G.G.K. Setten, the last expatriate Chief Research Officer, left and was succeeded by Abdul Rahman bin Mohamad Ali. The last foreigners to leave the Forest Research Institute were A.J. Vincent, Deputy Chief Research Officer, and B.A. Mitchell, Afforestation Officer. Francis S.P. Ng was recruited in June 1964 as Forest Botanist.

When an extension to the main office building was completed in 1965, the herbarium moved, in May, to the top floor of the new block. By 1965, the collection numbered 74,694 specimens. With this new scheme of things, and Kochummen and Ng attached to Forest Botany, the non-dipterocarp manual was again reemphasized and Timothy Charles Whitmore was engaged under the Colombo Plan Aid to reorganize the project to produce a Tree Flora of Malaya. Whitmore was with the FRI between September, 1965 and April, 1972. Kochummen became Forest Botanist in 1971 and Senior Forest Botanist in 1980, and Ng was Senior Forest Botanist from 1974 until 1978, subsequently assuming the post of Assistant Director of the Institute. The first volume of the *Tree Flora of Malaya* (Ed. Whitmore 1972), largely written by Kochummen, Whitmore and Ng, also received contributions of family accounts from other botanists in the region, *viz.* Peter F. Cockburn, Hsuan Keng and Benjamin C. Stone.

The development of the Herbarium and Arboretum subsequent to Malayanisation, and the individual achievements of Kochummen and Ng, are not here dealt with. The present account chronicles the beginnings of the Herbarium and Arboretum of the present Forest Research Institute of Malaysia at Kepong, and traces the roles of the people associated with these events and developments until Malayanisation in the late sixties.

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# Tree Species Enumeration of 0.5 Hectare on Halmahera

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**Abstract**

A plot of 0.5 ha in east central Halmahera in the Moluccas had 76 species, 31 families and 371 stems of trees ⩾ 10 cm dbh. It differed substantially from plots enumerated previously in Seram.

It is well known that within Malesia once one crosses Wallace's Line eastwards the tree flora becomes poorer. Many rain forests in fact show greater richness in the western (Sumatra, Malaya, Borneo) and eastern (New Guinea) regions of the archipelago than in the centre (Sulawesi and the Moluccas), and some groups are very rich in species at either west or east. These aspects of floristics are reflected by tree-species numbers on small plots.

There are a few counts which show some very rich forests in western Malesia; the largest counts ever recorded for rain forest come from Sarawak (223, 214 species/hectare of trees ⩾ 10 cm dbh; Proctor *et al.* 1983). For Kalimantan there are records of 149, 129 and 128 spp./ha (Kartawinata *et al.*, 1981), while for Papua c. 184, c. 181, c. 152, c. 145 spp./ha have been recorded (extrapolated from plots of 0.8 ha area; Paijmans, 1970). There are very few counts from central Malesia.

The exact location and shape of a small plot is likely to affect the number of species counted. Shortage of time has invariably prevented workers from simply adding more subplots to reach the asymptote of the species-area curve. This measure of abundance in species is thus not entirely satisfactory, but an accumulation of plot counts from different places will eventually give some fairly objective data on forest composition.

Thus, we offer here the first enumeration made on Halmahera, an island in north Moluccas, as a modest contribution to forest quantification.

The site lay on a broad ridge crest at 630 m over shale at 0°30'N, 125°30'E, near the logging camp at Tapayo, 20 km southeast of Dodinga on Telok Kau, on the central mountainous spine of the northeastern peninsula. The soil was a shallow reddish clay only c. 40 cm thick. The surface had a continuous thin leaf litter. The tallest trees were c. 40 m. Big woody climbers were rare. Most boles were clean of epiphytes and of adherent climbers (of which the most abundant were two *Freycinetia* spp. both only 'occasional'). There was a dense seedling carpet. The forest was mostly in the mature phase of the growth cycle, with a few small gaps formed by one or two fallen trees (Fig. 1). Otherwise big trees were 'dying on their feet', disintegrating *in situ,* and forming virtually no gaps.

The whole region had been recently heavily logged and we were only able to find a homogeneous intact patch of less than one hectare. Within this patch we enumerated all trees ⩾ 10 cm dbh on a single half-hectare plot, made up of 11 subplots of 0.04 ha plus 3 of 0.02 ha (Fig. 1).

Fig. 1. Plot layout and forest phase diagram. Gap-phase forest is left unshaded. Rest is mature phase.

In Fig. 2 we present the species-area curve, which shows signs of flattening out. In Table 1 we present a summary of floristics. Myrtaceae, Guttiferae and Lauraceae dominate the forest both in terms of species and stem numbers. We had a total of 76 species in 31 families on the half hectare, and 371 stems.

The only other published plots we know of for the Moluccas were enumerated on Seram island. There, on an area of 8 ha, comprising four transects each 20 × 1000m, only 54 species in 27 families were encountered (Sidiyasa & Tantra 1984). Such long belt transects are likely to maximise species recorded because of their length,

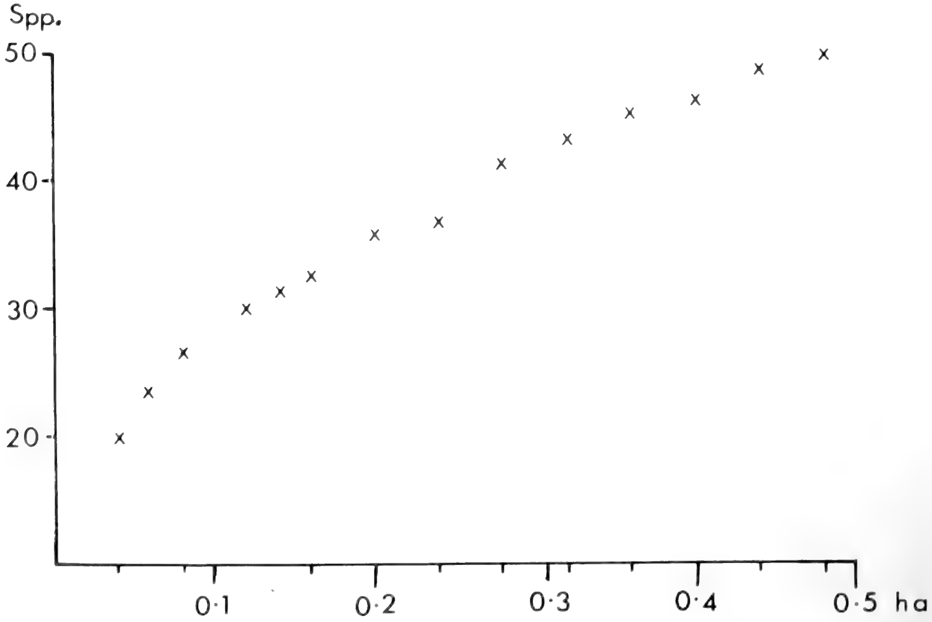

Fig. 2. Species-area curve.

Table 1. Families in descending sequence of abundance on the 0.5 ha plot. (For species authorities see Whitmore & Tantra in press)

| | | Total species | Total stems |
|---|---|---|---|
| Myrtaceae | 11 *Eugenia* spp. (30 + 7 + 9 × 1) | 11 | 46 |
| Guttiferae | *Calophyllum soulattri* (23 stems) | | |
| | 3 *Calophyllum* spp. (35 + 3 + 1) | | |
| | *Garcinia celebica* (31) | | |
| | 4 *Garcinia* spp. (6 + 3 + 1 + 1) | 9 | 104 |
| Lauraceae | *Cryptocarya* sp. (1) | | |
| | *Endiandra rubescens* (11) | | |
| | 2 *Litsea* spp. (9 + 7) | | |
| | 3 Lauraceae indet. (1 + 1 + 1) | 7 | 31 |
| Burseraceae | *Canarium vulgare* (1) | | |
| | 2 *Canarium* spp. (23 + 1) | | |
| | *Santiria* sp. (1) | | |
| | 2 Burseraceae indet. (2 + 1) | 6 | 29 |
| Myristicaceae | *Gymnacranthera forbesii* (3) | | |
| | *Gymnacranthera* sp. (1) | | |
| | *Horsfieldia* sp. (5) | | |
| | *Myristica* sp. (7) | | |
| | Myristicaceae indet. (2) | 5 | 18 |
| Euphorbiaceae | *Blumeodendron* sp. (1) | | |
| | *Macaranga* sp. TCW 3621 (28) | | |
| | *Macaranga* sp. TCW 3680 (2) | 3 | 31 |
| Theaceae | *Adinandra* sp. (1) | | |
| | *Laplacea* sp. (3) | | |
| | *Ternstroemia* sp. TCW 3669 (4) | 3 | 8 |
| Anacardiaceae | *Dracontomelon dao* (1) | | |
| | *Gluta* sp. (1) | | |
| | *Semecarpus* sp. (1) | 3 | 3 |
| Rubiaceae | *Gardenia* sp. (1) | | |
| | *Nauclea mitragyna* (1) | | |
| | *Nauclea* sp. (2) | 3 | 4 |
| Fagaceae | *Castanopsis buruana* (6) | | |
| | *Lithocarpus celebicus* (17) | 2 | 23 |
| Sapindaceae | *Pometia pinnata* (4) | | |
| | Sapindaceae indet. (1) | 2 | 5 |
| Dilleniaceae | 2 *Dillenia* spp. (3 + 1) | 2 | 4 |
| Leguminosae | *Archidendron* sp. (2) | | |
| | *Cynometra ramiflora* (1) | 2 | 3 |
| Meliaceae | *Aphanamixis polystachya* (1) | | |
| | *Aphanamixis* sp. (2) | 2 | 3 |
| Araucariaceae | *Agathis dammara* (11) | 1 | 11 |
| Dipterocarpaceae | *Anisoptera thurifera* (10) | 1 | 10 |
| Melastomataceae | *Memecylon* sp. (9) | 1 | 9 |
| Celastraceae | *Lophopetalum* sp. (4) | 1 | 4 |
| Ebenaceae | *Diospyros lolin* (4) | 1 | 4 |
| Juglandaceae | *Engelhardtia serrata* (4) | 1 | 4 |
| Sapotaceae | *Planchonella moluccana* (3) | 1 | 3 |
| Cunoniaceae | *Schizomeria serrata* (2) | 1 | 2 |
| Flacourtiaceae | Flacourtiaceae indet. (2) | 1 | 2 |
| Palmae | *Pinanga ternatensis* Scheff. (2) | 1 | 2 |
| Ulmaceae | *Gironniera subaequalis* (2) | 1 | 2 |
| Annonaceae | *Popowia* sp. TCW 3605 (1) | 1 | 1 |
| Elaeocarpaceae | *Elaeocarpus* sp. (1) | 1 | 1 |
| Lecythidaceae | *Barringtonia* sp. TCW 3639 (1) | 1 | 1 |
| Moraceae | *Ficus* sp. TCW 3642 (1) | 1 | 1 |
| Rhizophoraceae | *Gynotroches axillaris* (13) | 1 | 1 |
| Rosaceae | *Maranthes corymbosa* (1) | 1 | 1 |
| TOTALS | 31 families | 76 species | 371 stems |

Voucher specimens either deposited at BZF (most are solely fallen leaves) or, for TCW collection series, at BO, BZF, K and L.

in contrast to compact plots. On the Seram plots no family was well represented. Myrtaceae (6 species), Euphorbiaceae (5 species) and Ebenaceae, Guttiferae, Moraceae, Sapotaceae and Sterculiaceae (3 species each) were richest.

Both sites lie in rain forest climates, types A (Halmahera) and B (Seram) in the Schmidt & Ferguson (1951) scheme (see map Fig. 4.1 in Whitmore 1984). Neither forest had any noticeable seasonal-climate floristic element.

Stem number on our plot at 742/ha is high in comparison with most rain forests. The Seram plot at 390 stems/ha is about average (see Table 1 in Whitmore & Sidiyasa 1986).

The Halmahera and Seram samples are very different from each other. In the long term, interpretation of variation in forests between different parts of Malesia needs some kind of quantitative data base, towards which we publish this enumeration.

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# *Additions to* 'The Use of Tifgreen and Tifdwarf Bermuda Grasses in Two Singapore Golf Courses'

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Further to my recent publication of the report (Wong, 1986) on the performance of the two tifgrasses, Tifgreen and Tifdwarf, in the golf courses at the Tanah Merah Country Club (TMCC) and the Sentosa Golf Club (SGC), I was fortunate to have the opportunity of revisiting the Jagorawi Golf and Country Club near Bogor, Indonesia, on 7 January 1987. My first visit was six years ago when the first 9 holes were just ready for play. At the time the tees were covered with pure Santa Ana grass while the fairways and greens were respectively turfed with Tifgreen and Tifdwarf. It was already noticed that broad-bladed local grasses such as *Axonopus compressus* (Cow Grass) and *Paspalam conjugatum* were beginning to invade the fairways and workers were seen busy weeding these out. The resident superintendent at the time, however, assured me that with minimum weeding the turf could be kept pure. This has turned out to be otherwise.

As Jagorawi was our source of the grasses for TMCC and SGC, I made it a point to look very closely at the turf as we played along so as to establish a visual comparison between the situation in Singapore and that at Jagorawi *vis-a-vis* the fate of the introduced grasses. Jagorawi, just like TMCC and SGC, used Santa Ana for the tees, Tifgreen for the fairways and Tifdwarf for the greens, and just like our two courses in Singapore the intention was to keep the turf as pure cultures. After having seen the whole course during the round of golf, I have to say that the present situation at Jagorawi is very similar to that at TMCC and SGC — except for the greens, the Tifgreen in the fairways and the Santa Ana on the tees have almost been totally replaced by other grasses and sedges.

The whole range of species of the grasses and sedges occurring in TMCC and SGC could be found in Jagorawi but the density patterns are very different in the two places. In TMCC and SGC there are more of the coarser species, such as *Brachiara distachya, Axonopus compressus,* and *Cyperus radians* whereas in Jagorawi, species with finer habits have come into dominance. These are the Serangoon Grass, *Digitaria didactyla,* a species of *Eragrostis* and patches of *Polytrias amaura.* The rather fine sedge, *Cyperus kyllingia,* is also common but not as dominant as in the two courses in Singapore. With the finer grasses dominating the scene, the Jagorawi course has a much more uniform look than our two courses.

*Cyperus radians,* the coarse sedge with a tufted rosette habit, found so commonly in the two courses in Singapore, is hardly seen at Jagorawi. This may be due to the better drainage of the volcanic soil in the latter place. It may be recalled that this sedge comes into prominence when there is locally impeded drainage. That this should happen on a course constructed with a sand overburden on clayey fills, such as is done in Singapore, may seem surprising. Sand is supposed to be rather free draining. Unfortunately the sand overburden that was laid is not deep enough in certain spots, and since the underlying clay is rather impervious, water tends to be retained at the distinct interface, particularly if the topography is flat at the spots in

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*Mr. Wong is a founder member of TMCC and was at various times serving on its management committee and the Sentosa Golf Board.

question. This would cause local ponding during wet spells or when the place is over watered. Volcanic soil on the other hand is well known for its better structure and this accounts for better drainage and hence the absence of this hydrophilic sedge.

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Wong, Yew Kwan (1986). The Use of Tifgreen and Tifdwarf Bermuda Grasses in Two Singapore Golf Courses. *Gard. Bull. Sing.* 39: 203-214.

# Morphological Adaptations for Bird Pollination in *Nicolaia elatior** (Jack) Horan (Zingiberaceae)

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*R.W.T.H. Aachen, West Germany*

**Abstract**

A report is given in detail on the behaviour of *Anthreptes malacensis* when visiting the inflorescence of *Nicolaia elatior*, with special reference to the Singapore Botanic Gardens. It is shown how in *Nicolaia* ornithophily became a realistic alternative to psychophily by the formation of a dense inflorescence unit, the main steps of which being the aggregation of flowers and the expansion of (sterile) bracts.

*Nicolaia elatior* is often cultivated in tropical gardens. Its popularity is attributed to the spice which the flower buds provide and the ornamental value of the intensively red and glossy blossom† (plate 1) attracting nectar-searching animals, especially birds. Knuth (1904, 183) had observed sunbirds on the flowering heads of *Nicolaia elatior*, but he took them for 'more harmful than useful' visitors. His

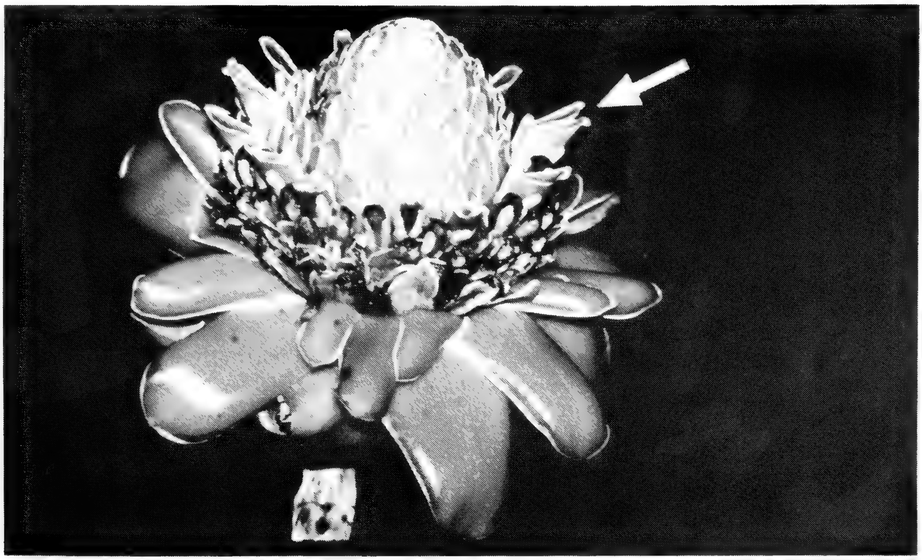

Plate 1. The flower head of *Nicolaia eliator* surrounded by showy, extrafloral bracts.

Within the inflorescence, the open flowers form a whorl and present their yellow signals (*arrow*); *below*, ripening fruits; *above*, flowers still in bud.

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* More familiar synonyms are *Elettaria speciosa* Bl. and *Phaeomeria magnifica* (Roscoe) Schum. For a more complete list see Valeton (1921: 138), Burtt and Smith (1972: 210-211), and Weber (1980: 152). Presently, *Etlingera elatior* (Jack) R.M. Smith is the correct name. This new combination (Smith, 1986) has reduced *Nicolaia elatior* to a synonym.

† The term 'blossom' is used in the sense of Faegri & v.d. Pijl (1979: 21), that is as an ecological term. In the morphological point of view, a blossom may be an inflorescence (pseudanthium), a flower (euanthium) or a part of a flower (meranthium).

opinion was that the birds visited the blossoms only for catching insects there, and if they happened to insert their bill into the blossoms it was only incidental and pollination was not effected. My observations at the Botanic Gardens in Singapore strongly supports the view that *Anthreptes malacensis* is a pollinator.

*Nicolaia elatior* (Jack) Horan is a perennial herb which grows naturally in primary and secondary forests in SE. Asia. Frondose leaves on the vegetative stems measure several meters long and loosely shade over the reproductive, shaft-like stems, which are 1-2 m long. On these are exposed a terminal flower head. Apart from the large showy leaves which are integrated into the habit of the blossom these reproductive stems bear only small bracts.

The inflorescence looks like a simple cephalium with about 300 flowers spirally set on an undetermined apex. But recently, Weber (1980: 158) and Kunze (1985: 127) have shown that this flower head is a simple, highly reduced polytelic thyrsus.

The base of the flower mass is surrounded by large showy bracts, which form a pseudocorolla of 20-cm diameter (pl. 1) and are the most conspicuous element of the blossom. Except for a narrow pale margin, both sides are intensively carmine and show a fine brightness which is caused by the waxy surface. The proximal leaves are sterile and follow on abruptly the inconspicuous bracts of the shaft while the distal, flower-subtending bracts gradually reduce in size. Before flowering, the showy leaves completely envelop the flower buds; then, during anthesis they stick out horizontally and finally, in the postfloral phase, they hang down retrorsely. Anthesis of a head is 3 weeks. Every day, the flowers of a whorl would open simultaneously and fade a few hours later. Thus the flowering zone shifts upwards along the inflorescence axis which elongates from 5 to 15 cm. While the flowers at the top are still in bud, young fruits would have developed at the base.

The flower is sessile and zygomorphic (pl. 1, figs. 1 & 2). Its characteristic boat-shape is brought about by the labellum* which forms a staminodial tube together with the fertile stamen (fig. 2). The style is — in the typically zingiberaceous manner — fixed in its position by the anther (fig. 4). Pollen-sacs and stigma are oriented towards the labellum (fig. 3). By the unique arrangement of the labellum, anther and stigma, pollination occurs whenever a sucking organ is dipped into the tube (fig. 5) — as Knuth (1904) has already described in some detail.

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* Weber (1980) interprets the labellum as a homologon to the two inner staminodes of the zingiberaceous flower. Kunze (pers. comm.) however is convinced that the labellum is represented by all the five staminodes together.

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*Facing Page*

Fig. 1 Habit of a flower of *Nicolaia elatior*.
*pr*, prophyll; *ca*, calyx; *co*, corolla lobe; *lab*, labellum.

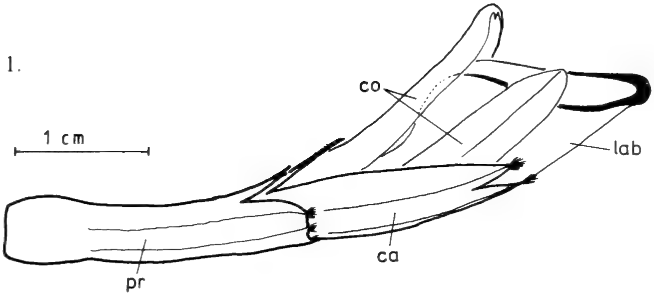
Fig. 2. Diagram of a flower of *Nicolaia elatior* (empirical, see note 3 on p. 41).
*sb*, subtending bract; *ax*, axillary bud; *sta*, fertile stamen; *ep*, epigynous gland; *gyn*, gynoecium; *solid:* staminode tube.

Fig. 3. Optical longitudinal section showing the position of the anther-stigma-complex in relation to the labellum.
*sty*, style; *th*, theca; *ko*, connective; *fil*, filament; *hb*, hairy belt.

Fig. 4. A flower of *Nicolaia elatior*, longitudinally opened.
*sti*, stigma; *dl*, dehiscence line of pollen sac; *hg*, hairy groove of the filament.

Fig. 5. Flower of *Nicolaia elatior* as pollination apparatus.
*to*, tongue; *bi*, bill; → pollen transference; *nr*, nectar reservoir.

1.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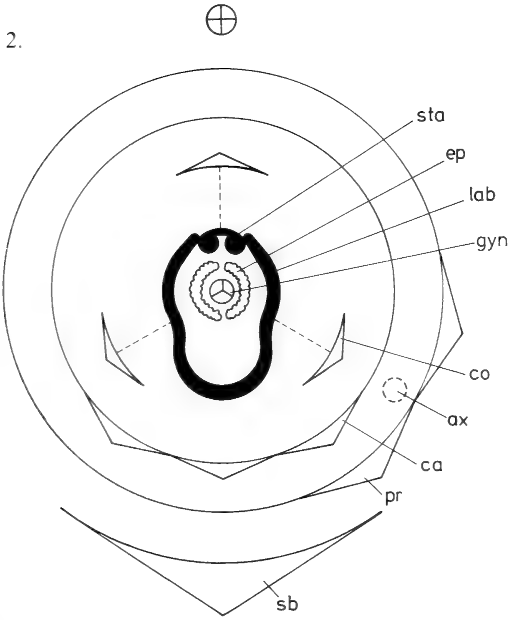
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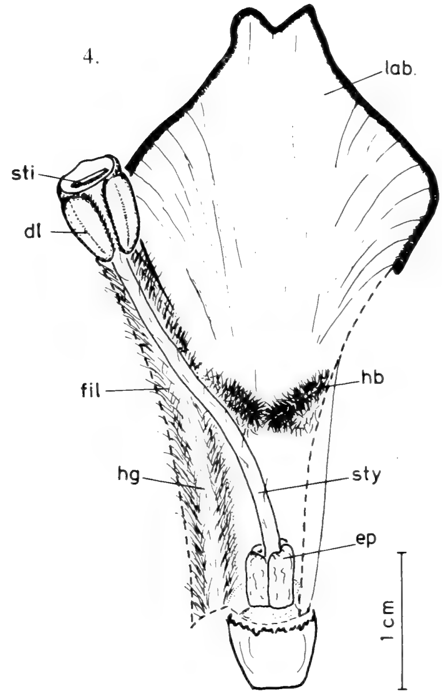
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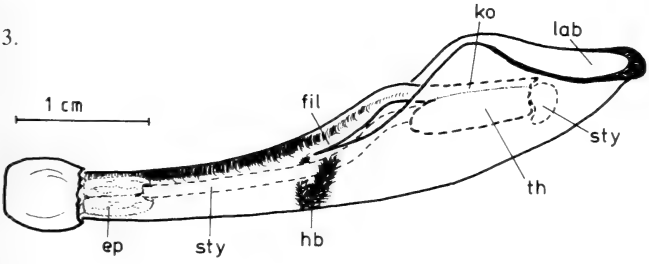
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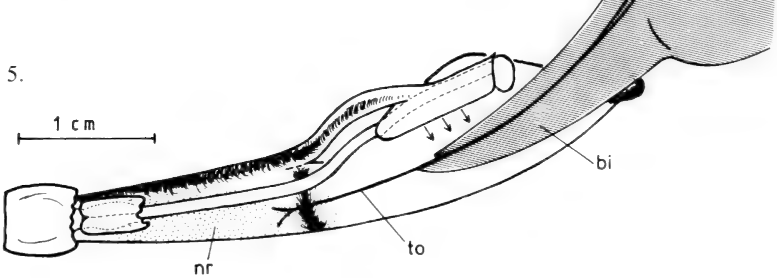
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Nearly all parts of the flower are more or less red coloured. Exceptions are the pale, hardly visible anther and the very conspicuous, intensively yellow margin of the labellum. The open flowers present these yellow parts like signals pointing to the nectar-store. This may be of great importance, because the flowers lack — at least not detectable — any alluring odour. Nectar is produced in great amount. It is secreted by epigynous glands at the bottom of the flower and is stored in the staminode tube, which functions as a nectar-reservoir (fig. 5). As is shown in fig. 4, the inner surface of the tube is partly covered with long hairs. The filament is densely hirsute and, approximately in the middle of the tube, there is a thick hairy belt. Here, the hairs are arranged around two cuticulous protuberances running diagonally from the filament border to the median of the labellum. It is quite reasonable to assume that these hairs let the nectar move up by capillary absorption.

*Upper right*

Plate 2. A male *Anthreptes malacensis* (scale: 2 cm). The skin was kindly made available by the Zoological Museum in Bogor, Indonesia.

*Left*

Plate 3. A male *Anthreptes malacensis* visiting the flower head of *Nicolaia elatior* in the Botanic Gardens, Singapore.

*Lower right*

Plate 4. A skin of *Anthreptes malacensis* with the head and bill artificially inserted into a flower tube to simulate the natural position when pollinating (nat. size).

I had the opportunity to observe for three weeks, flowering plants of *Nicolaia elatior* and to record the blossom visitors. The most frequent and conspicuous was a sunbird with a metallic sheen, the male *Anthreptes malacensis* (pl. 3). At intervals, about 2-3 times hourly, it flew from the nearby *Pandanus*-thicket directly to one of the flowering heads and landed on it.

There was no insect-picking at all though a lot of small ants, spiders and others were available. After a short look around — probably to check on the safety of the place — the bird inserted its bill into an open flower. It remained in that position for up to 5 seconds. After that, the bird dipped its bill systematically into a second, third and fourth flower. Its movement was restricted to a mere turnabout, step by step, such that the bill was always exactly above the next open flower. Standing on the top of the blossom, the bird only had to bend the front part of its body downwards to reach the flower tube (pl. 3). As long as the bird was undisturbed, it exploited up to 7 flowers per inflorescence, thus, less than half of the open flowers in a single turn. Generally, before flying back into the thicket, it would look round for more, then visit a second and sometimes even a third inflorescence. In its resting place, the bird was mostly engaged in cleaning its bill and its plumage. It rested for 10 minutes or as much as an hour before it returned to visit the blossoms in the described manner.

Obviously, the blossoms of *Nicolaia elatior* attract *Anthreptes malacensis* Scop. Though this observation was made in an artificial setting, I am convinced that *Anthreptes malacensis* is one of the natural pollinators of the plant. This is supported by the remarks of Werth (1915) and Porsch (1924) concerning bird pollination in SE. Asia. Besides that observation, I have seen another male *Anthreptes* visiting *Nicolaia elatior,* this time in a natural site near Bogor, W. Java. In general *Anthreptes malacensis* is very common in SE. Asia and shares the same biotope with *Nicolaia elatior* (King *et al.* 1984: 413). As with all Nectarinidae, it is characterized by a specialized tongue which is well constructed for sucking honey: the tip is forked and able to lap up drops of nectar while the tongue itself is folded over its whole length forming, together with the bill, a perfect sucking tube (Werth 1900: 256-7).

With regard to bird pollination,

1. it is clear that *Nicolaia elatior* first of all attracts the bird optically by the intensive red colour of the blossom — a colour which is known to be quite common in ornithophily. The concentration of the flowers to a highly compacted head and the enlargement of the extrafloral bracts promote the attractiveness of the blossom. In terms of phylogeny, the primary function of the bracts probably has been to protect the flowers against rain (Knuth, 1904: 182) which was then followed by another evolutionary step, the transformation of the whole blossom into an attraction apparatus. A comparable shifting of function of plain bracts from phylogenetically old structures to attraction units can also be seen in the blossoms of some Verbenaceae (Classen 1986).

Presumably the display of the blossom plays an important role in the efficient attraction of a pollinator, which is able to vagabondize distantly. In *Nicolaia elatior* it is the stem again which provides the bird with a lookout to exploit nearby flower tubes. As the inflorescence axis slowly elongates during the flowering period, there is a constant distance between the bird and the opened flowers. This is, of course, a very favourable prerequisite to a successful bird pollination. It is the direct consequence of the aggregation of flowers. So, even the aggregation seems to be an equipment of prior rank for bird pollination.

2. *Nicolaia elatior* provides a landing and sitting place to the bird. It is the top of the blossom which is enlarged by the dense aggregation of bracts and flowers. And it is the stem again which provides the bird with a lookout and to exploit nearby flower tubes. As the inflorescence axis slowly elongates during the flowering period, there is a constant distance between the bird and the opened flowers. This is, of course, a very favourable prerequisite to a successful bird pollination. It is the direct consequence of the aggregation of flowers. So, even the aggregation seems to be an equipment of prior rank for bird pollination.

3. *Nicolaia elatior* produces a high amount of nectar to reward the bird for its visit. The nectar is clear and liquid. The concentration of sugar (taken at random with a field refractometer) was 18-28% in the open flowers and only 5-8% in the

nectar of just fading flowers, which are not visited any more by the bird. The presentation of the contrasting yellow signal helps the bird to find the entrance to the nectar store. Pollination should take place as soon as the bird has dipped its bill into the flower tube: At first, the pollen brought along from another flower is wiped off on the stigma and then the pollen of the flower actually under visitation is deposited on the underbill (fig. 5). As the pollination mechanism is very much the same for all kinds of pollinators, Knuth's description (1904: 182) concerning pollination by butterflies is acceptable for bird pollination too. The small membranous lip below the stigma assures that the pollen will not touch the stigma when the bill is retracted.

According to Knuth (1904: 183) the flowers are said to be damaged by the hard and curved bill. This was the main reason that he did not consider that bird pollination takes place in *Nicolaia elatior* — an objection which has already been rejected by Werth (1915: 370). I did not notice any flower being damaged by the bird — all staminodial tubes remained completely intact. Obviously, the flower is very well adjusted to the bill, the staminodial tube and the bill showing a high similarity in curvature (fig. 5, pl. 4). As the labellum is hardened on its abaxial side and equipped with a slippery inner surface, its construction is just a slide and would function as a leading groove for the bill. The ovary is protected by its hypogyny and by the length of the flower tube (up to 5 cm). As the nectar is capable of rising within the tube, it is by no means necessary that the bill (or tongue or proboscis of any visitor) is as long as the tube. So, even bees and butterflies with quite short sucking organs can become successful pollinators (see Knuth 1904: 182).

4. *Nicolaia elatior* flowers continuously. There are always several inflorescences of different ages on any one plant and each of them has a flowering period of about 3 weeks. Thus the plant probably can make nectar available to its visitors throughout the year.

Without doubt, the blossom of *Nicolaia elatior* is adapted to bird pollination. But, it is not exclusively an ornithophilous blossom, it is visited as well by diverse butterflies especially *Lycaenidae* and *Danaidae.* The insects sit down on one of the outer bracts and insert their sucking organ bowlike from below into the flower tube. Though the sucking behaviour is quite different, the success of pollination is unquestionable. In general, 'the differences between the psychophiles and ornithophiles are rather indistinct' (Faegri & v.d. Pijl 1979: 126) and so it is idle to separate them artificially.

In terms of phylogeny we can draw a consistent line: recalling the specific parameters which promote bird pollination it is clear that in the case of *Nicolaia elatior* the transition of the zingiberaceous inflorescence into an inflorescence-blossom (pseudanthium) has been the most important step. While psychophily — based on the flower structure — is also possible without any special aggregation and modification of the inflorescence, the development towards ornithophily only depends on the special inflorescence-construction, especially on flower aggregation, bract integration and display by a shaft-like stem.

So, the flowering head of *Nicolaia elatior* shows an example for the evolution of an inflorescence-blossom, one that opens new pollination chances for a certain species. This may also help to understand how the succession of well operating pollinators happened in the evolutionary process.

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# Ecology of the Trees of Bukit Timah Nature Reserve

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**Abstract**

An inventory was carried out in Bukit Timah Nature Reserve to study the specific composition of the trees. For the sampling a systematic layout was used. The sampling unit was a cluster, with 4 circular tenth acre sub-units, so that the area of each cluster is 0.4 acre. Enumeration was done for all trees down to 24 inches (c.61 cm) gbh but for each cluster, in one of the circular subunits enumeration was down to 12 inches (c.30.5 cm) gbh. The idea was to have smaller-girthed trees to indicate recruitment.

In all, the 20-cluster sample, covering some 8 acres (3.24 ha) yielded 889 trees, belonging to 44 known families with 212 species. Twenty individual trees in 13 clusters could not be identified at all.

The specific composition of the forest conforms to that of a Coastal Hill Forest according to Symington's classification of the forests of Peninsular Malaysia. The dipterocarps show family dominance with 125 individuals out of a total population of 889 trees while the family Euphorbiaceae show the highest number of genera (11) and the greatest number of species (22). The other families with species preponderance are the Anacardiaceae, Burseraceae, Lauraceae, Myrtaceae and Leguminosae.

A parameter, called the Distribution Index (DI), is used to indicate spatial distribution (lateral spread) of the species within the community. This is simply the number of clusters in which the species occurred, its number of individuals being ignored. It is reckoned that this parameter, tabulated side by side with the sample total of the species affords a quick visual appreciation of the ecological influence of the species. In the sample, 121 species have been found to have a DI of unity, 41 with 2, 13 with 3, etc. Only 5 species have a DI equal to or exceeding 10.

A stand curve, and a species/area curve are given. The stand curve, an inverted "J", shows the typical content of uneven-aged stands and indicates good representation of trees in different girth classes. The species/area curve does not show flattening out, indicating that the sample has not reached a size which would have included most of the species.

For trees with gbh. $\geqslant$ 24 inches the mean density of the forest is 86 stems/acre compared to 103.3 stems/acre for some stands in a similar forest type in Malaysia. The difference is found to be statistically significant at the 0.05 level. The *Mischungsquotients,* varying between 1.3 and 2.0, however, compare well with those of stands in Malaysia and indicate great complexity of species.

The hypothesis is put forward that despite the small size of the Reserve and its isolated nature the species which are peculiar to the Coastal Hill Forest type and wielding structural and numerical dominance as a whole, would survive over a long period of time because their progeny have an innate ability to grow up in the shade within the ambit of the parent trees. Because of this, at any one time they have individuals of all sizes in the forest ranging from saplings through pole-sized to mature trees. This is a guarantee to species survival. On the other hand, species with low density which are not widespread and whose saplings require canopy opening to grow up, may gradually die out, the reason being that the chance opening of the canopy in their vicinity may not coincide with their fruiting, and a tree may die before such an opening. The demise of a tree itself can cause an opening in the canopy but again it may occur at a time when its saplings are completely absent. All these factors may lead to a decline in the overall floristic composition of the forest.

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# I. Introduction

The forest on Bukit Timah Hill was made a nature reserve just before the Second World War and is protected under the Nature Reserves Act. The area is about 75 ha. (185 ac.) and the summit of the hill at 163.5 m (536 ft.) is reputed to be the highest point in Singapore.

Geologically the area consists of granite and because this rock type is used extensively as a road metal and construction material several quarries have made extensive exploitation for the rock west and south of the Reserve. The topography ranges from gradual to steep and in some places the land falls to merge with steep-sided gulleys where granite outcrops and boulders abound. Outcrops can also be seen in many other places within the Reserve and along its boundary.

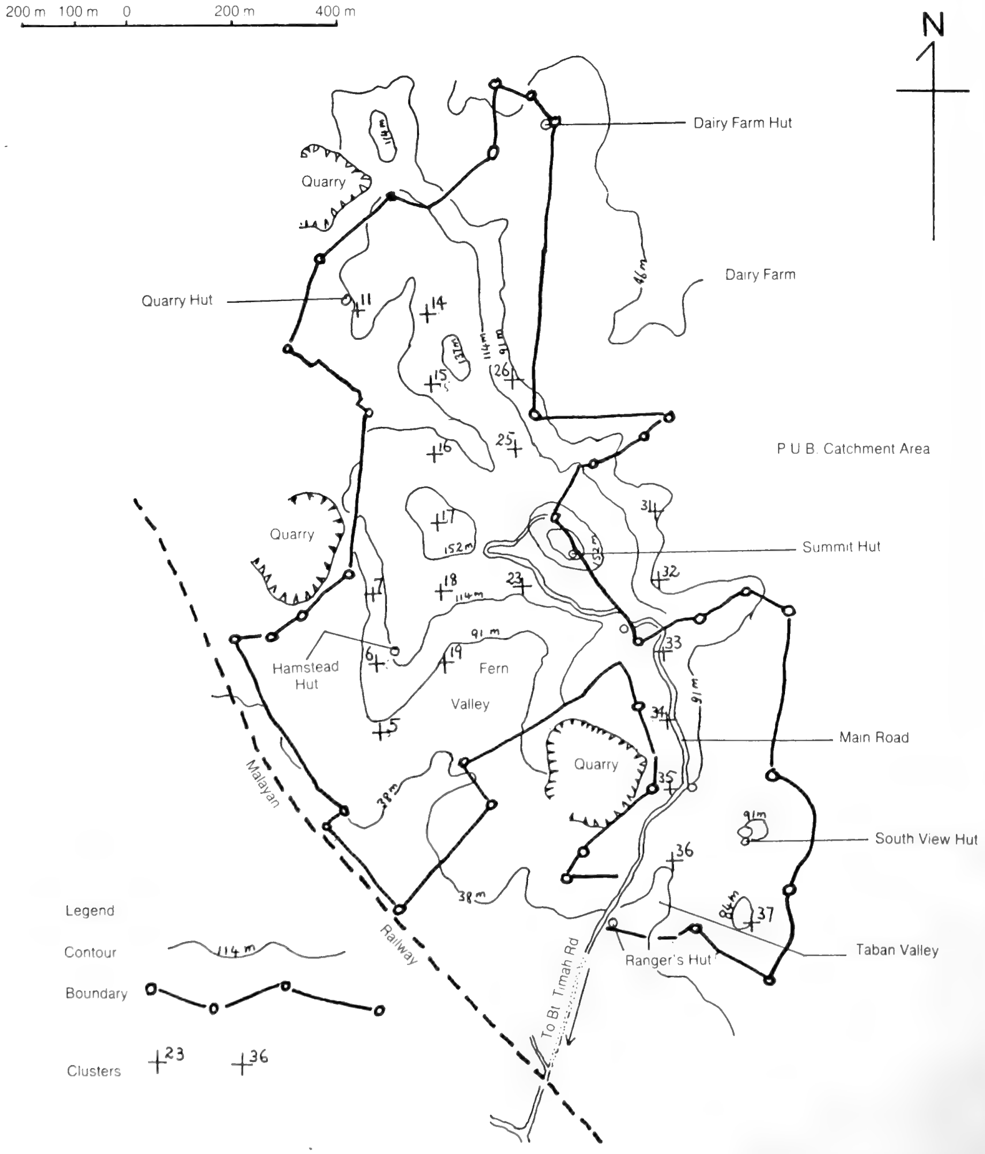

Fig. 1. Sketch Map of Bukit Timah Nature Reserve Showing Location of Sampling Units.

Until very recently to all intents and purposes Bukit Timah could be considered as part of the central catchment area in Singapore, being located on its western fringe and separated from it only by a pipe-line carrying water from Johore to Singapore. With the recent completion of the Pan Island Expressway, east of the Reserve, however, it is now completely isolated with non-forested areas on all sides. The Expressway is a six-laned major highway with ample road reserve.

The vegetation consists of stands of high forest and pockets of secondary forest along the reserve boundary at different stages of ecological succession ranging from open scrubland to pole-sized forest. The high forest appears undisturbed and is of a primary nature. In terms of specific composition the forest should best be classified as a Coastal Hill Forest (vide Symington (1942)). This is characterised by *Shorea curtisii* occurring at low elevation and its association with species which would otherwise occur only or predominantly in Hill Dipterocarp Forest, such as *Anisoptera curtisii* and *Artocarpus lanceifolius*.

At the time when Symington wrote his Manual of Dipterocarps it was thought that *Shorea curtisii* was probably endemic to the Malay Peninsula. However, more recent taxonomic works by both Meijer (1964) and Ashton (1982) have reported the presence of *Shorea curtisii* in the hills of Borneo and on islands off the Sumatran coasts. There is, however, no ecological work to elucidate its association with other species. It is, therefore, uncertain whether there exists a Coastal Hill type of forest in these places, similar to that under reference. If none exists then Bukit Timah is unique in that it is the southernmost habitat of a Coastal Hill Forest.

The Hill is botanically famous because it is the type locality of many species, the result of its being the collecting ground of many famous botanists, such as Ridley, Burkill, Holttum and Corner. In recent years teachers and students of both universities and secondary schools have made observations on the plant communities and animals in the Reserve (see for example, Whitmore & Wong (1959). Recently a guide book (1985) has been published in which common plants and animals are featured. As far as it was known before this survey was carried out no quantitative study had ever been made on the ecology of the trees. The survey was therefore initiated so as to create a scientific record of the tree species and their distribution in the Reserve. The work was carried out as an activity of the Singapore Branch of the Malayan Nature Society and the field work spanned a period of some three and a half years between June, 1974 and January, 1978. The actual area covered by the survey was only 3.24 ha (8.0 ac.). The apparently long period required to achieve this lies in the fact that field work was carried out as Sunday outings, once a month, and sometimes inclement weather rendered some Sundays impossible for work.

## II. Method

### *(a) Design and Layout*

The sampling units were located systematically. A systematic layout was preferred because although the Nature Reserve is relatively small there is great variation in topography and in the vegetation to be studied. As the study was not intended to be a statistical exercise but one which was aimed at revealing as much as possible the character of the forests, a random sample might not give the uniform spread of the sampling units over the Reserve. At the time of the survey a map of the Reserve with an Imperial* scale of 1 inch = 150 yds (approx. 1 cm = 54 m) was used as the base map for the sampling. A one-inch grid was laid over the map; the intersections

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*The survey was initiated before the Metric System was adopted in Singapore. In order to facilitate direct comparison with results obtained in Malaysia and to avoid sometimes meaningless conversions, it was decided to present the results of the survey using the Imperial System.

of the grid were used as the centres of the sampling units. There were some 40 possible sampling units but only 20 could be completed during the period mentioned earlier. A map of the Reserve with the positions of the sampling units appears in Fig 1. It will be noted that two of the units, No.31 and No.32 were located outside the Reserve boundary but they were included in the survey as the forest appeared uniform and continuous with the forest within the Reserve boundary. (See, however, Section III(c) concerning No. 32.)

Each sampling unit is a cluster of 4 circular plots (sub-units) each with a radius of 37.25 ft. (c. 11.35 m) arranged along the cardinal directions (see Fig 2). The plot centre is 55 ft. from the cluster centre. A circular plot of 37.25 ft. radius has an area of one tenth acre, so that a cluster covers an area of 0.4 acre. Unless otherwise stated, the cluster forms the basis of the various analyses presented in this report.

### *(b) Location of the Clusters and Circular Plots*

The job was made easy by the many paths and junctions present in the Reserve reference to which cluster positions could be located by the use of a compass and a 100-ft measuring tape. In order to correct for slopes the tape was pulled as horizontally as possible when measuring distances. If need be, such as on rather steep slopes, measurement was done step-wise for short distances instead of for a whole 100 feet.

Once the cluster centre was located, the tree nearest to the spot was marked and this was used as the working centre for the cluster. The centres of the 4 circular plots were located with reference to this tree. Likewise, trees were used to mark their centres. If they were of enumerable size they would be enumerated; otherwise they would be ignored during the enumeration.

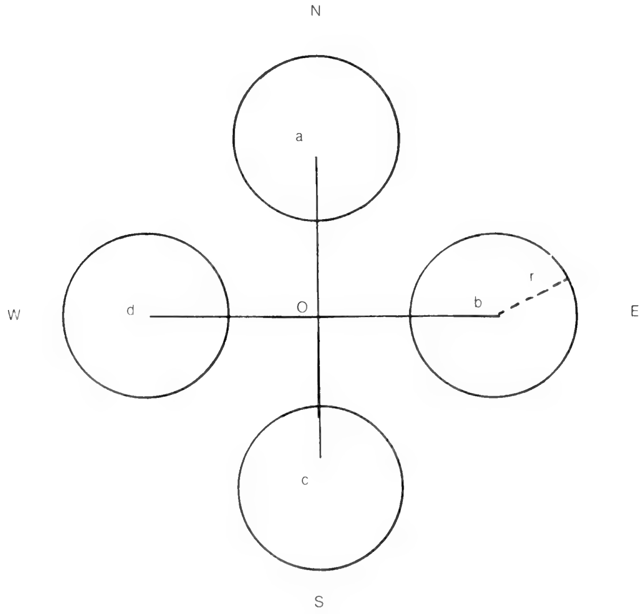


Fig. 2. Configuration and Size of the Sampling Cluster. O = Cluster Centre, Ob = 55 ft., r = radius of sub-plot = 37.25 ft., a,b,c,d, are respectively centres of sub-plots A,B,C,D. N,S,E,W are the cardinal points. Each sub-plot has an area of 0.1 acre. The area of the cluster is therefore 0.4 acre.

A quick inspection was made to ensure that none of the circular plots of the cluster would fall on man-made areas, such as a foot path or boundary. If any did, then the cluster centre was adjusted so that the plot(s) would avoid such an object as far as possible. Other than this, cluster location adhered strictly to what was indicated by the map.

Marking the sampling units with existing trees made our field work much easier than if we had to carry timbers or other similar materials to site for plot or cluster demarcation. Further, the circular plot was not demarcated. The boundary was the circumference, within seeing distance from the centre where the team leader, doing the booking, would be standing. When in doubt, a boundary tree was checked with the tape to see if it was in or out of the plot.

### *(c) The Enumeration*

Within the circular plot all trees with a girth at breast height (gbh — 4 ft. 6 ins. or c. 1.37m from the ground) of 24 inches (c. 61 cm) or larger were measured for girth. But for each cluster, Plot A formed a special sub-sample in which girth measurement included all trees down to 12 inches (c. 30.5 cm). The idea was to use this to indicate recruitment and regeneration. For trees which had buttresses taller than 4 ft. 6 inches, measurement was done above the buttresses and if the buttresses were too tall to be reached, then an estimate for the girth above buttresses was made. In the case of species which have a tendency to produce coppiced shoots from ground level, the girth of each coppiced stem, meeting the requirement of minimum girth at breast height, was measured.

In the enumeration the book was closed after finishing each circular plot.

The choice of 24 inches as the minimum girth in the enumeration was somewhat arbitary. In order to get a good picture of the composition of the forest in relation to recruitment and regeneration, the lower the girth limit the more accurate the information. Indeed for regeneration study enumeration of the seedling population is essential. However, it is also a fact that for rain forest ecology, the smaller the tree the more difficult it is to identify and the present study shows that if we had lowered the enumeration girth for all plots to 12 inches instead of 24 inches, then we would have had to deal with a population nearly 70% larger than what we have got. In absolute terms we would have had to measure and identify an additional 600 odd trees. This would have been too cumbersome for Sunday outings!

### *(d) Species Identification*

For this we relied mainly on sterile characters of the species. As we were working in a nature reserve, bark cut for identification purpose was kept to a minimum. Using such characters one had no difficulty identifying most of the larger trees, but for smaller trees, in many instances, we had to collect the fallen leaves and send them to the herbarium of the Botanic Gardens for further identification. In this study some 20 trees could not be identified at all. In the various lists presented in this report, the class called "Unknown" is the sum total of such difficult cases. (See Section III (b) for comments and plant names and their revisions.)

### *(e) Compilation and Analysis of Data*

The bulk of the compilation and analyses was done using dBase III Plus, on an IBM PC, with a capacity of 640 KB and with two disk drives. dBase III Plus is a widely known and widely used software package but for our present study it has been found that the features mentioned below are examples of useful commands for our compilation and analyses. Using the "Index" mechanism followed by the "Total" command, one could generate a complete species list with sample total for each species. Indexing in association with the "Set Unique" command also segregates species into mutually exclusive groups in different clusters. This facilitates species/area curve construction.

The programme is also extremely useful for the calculation of basal area by cluster with each figure being achieved by a single command! It also enables blocks of data, for example, lengthy tables, etc. to be transferred to a word-processor for further editing and reporting.

## III. Results

### *(a) Some Stand Parameters*

Table 1(a) presents some stand parameters of different clusters. Column 2 in the Table gives the actual number of stems encountered in the 0.4 acre cluster. Each figure is multiplied by 2.5 to convert it to number of stems per acre and the converted figures appear in Column 3. Column 4 gives the number of species present in each cluster. The *Mischungsquotient* (see Richards, 1964) of Column 5 is obtained by dividing Column 2 by Column 4 and it is simply the number of individuals per species within the stand. This is used as a measure of the degree of complexity of the stand. The larger this quotient is, the fewer the number of species in the particular stand.

Table 1(a). Some Stand Parameters — Bukit Timah Nature Reserve.
(Based on trees with gbh >=24 inches).

| Clust. Number (1) | Stem No. In The Cluster (2) | Stem No. Per Acre (3) | Species No. In Cluster (4) | Misc. Quotient (5) | Basal Area/Acre (6) |
|---|---|---|---|---|---|
| 5 | 28 | 70 | 19 | 1.5 | 125 |
| 6 | 42 | 112 | 28 | 1.5 | 168 |
| 7 | 38 | 95 | 22 | 1.7 | 177 |
| 11 | 42 | 105 | 27 | 1.6 | 136 |
| 14 | 37 | 92 | 25 | 1.5 | 160 |
| 15 | 39 | 97 | 27 | 1.4 | 118 |
| 16 | 30 | 75 | 25 | 1.2 | 97 |
| 17 | 32 | 80 | 20 | 1.6 | 115 |
| 18 | 24 | 60 | 23 | 1.0 | 95 |
| 19 | 24 | 62 | 20 | 1.2 | 105 |
| 23 | 32 | 80 | 19 | 1.7 | 149 |
| 25 | 53 | 130 | 6 | 8.8 | 96 |
| 26 | 33 | 82 | 11 | 4.7 | 70 |
| 31 | 39 | 97 | 24 | 1.6 | 125 |
| 32 | 50 | 125 | 25 | 2.0 | 176 |
| 33 | 27 | 67 | 21 | 1.3 | 103 |
| 34 | 33 | 82 | 23 | 1.4 | 114 |
| 35 | 23 | 57 | 19 | 1.2 | 86 |
| 36 | 24 | 60 | 7 | 3.4 | 76 |
| 37 | 37 | 92 | 14 | 2.6 | 132 |
| * Total | 687 | 1720 | 405 | | 2423 |
| Mean | 34.3 | 86 | 20.2 | | 121.1 |

Column 6 gives the total basal area of each cluster. The basal area of a tree is simply its cross-sectional area at breast height and that for the stand is the sum of the basal area of all the trees within that stand. This is a density parameter.

Table 1(b). Densities of some Malaysian Stands of Coastal Hill Forest. (Trees with gbh>=24 ins.)

| Location | Elevation (ft.a.s.l) | Plot size (acre) | Plot Total | Stems/ acre |
|---|---|---|---|---|
| Jarak Is. | 50 — 200 | 0.5 | 40 | 80 |
| | 200 — 350 | 0.5 | 51 | 102 |
| | | 1.0 | 91 | 91 |
| Rumbia Is. | 20 — 150 | 0.5 | 59 | 118 |
| | 150 — 300 | 0.5 | 53 | 106 |
| Kg. Gajah | 300 — 500 | 0.5 | 41 | 82 |
| Perak | 350 — 400 | 0.5 | 49 | 98 |
| | | 1.0 | 90 | 90 |
| Banang | 350 — 500 | 0.5 | 50 | 100 |
| Perak | 700 — 850 | 0.5 | 40 | 80 |
| | 500 — 650 | 0.5 | 54 | 108 |
| | 250 — 350 | 0.5 | 64 | 128 |
| Pangkor Is. | 50 — 200 | 0.5 | 54 | 108 |
| Soga, Johore | 350 — 500 | 0.5 | 61 | 122 |
| | 900 — 1100 | 0.5 | 60 | 120 |
| Gunong Raya Langkawi Is. | 200 — 400 | 0.5 | 60 | 120 |
| | | | Total | 1653 |
| | | | Mean | 103.3 |

Source: Wyatt-Smith (1963), Table 12, Pg. III — 14/20, only figures for gbh>=24 ins have been extracted for conversion into densities presented here. All the non-island Forest Reserves, except Kg. Gajah, are within 3 to 6 miles from the sea. Kg. Gajah is within 15 miles from the sea.

Table 1(b) presents some figures on number of stems per acre derived from different forest reserves with Coastal Hill forest in Peninsular Malaysia, viz Jarak Island, Rumbia Island, Pangkor Island, Banang, Kampong Gajah, Soga and Gunong Raya on Langkawi Island. The relevant figures are extracted from Wyatt-Smith (1963).

The purpose is to compare this parameter with the figures presented in column 3 of Table 1(a).

The density figures of the Bukit Timah Forest show rather wide variation, with the values ranging from 57 to 130 stems per acre. The mean of the 20 clusters is 86 stems per acre. A t-Test, dealing with unpaired variates but with the variance of the two samples being equal, shows that this mean is significantly different from that of 103.3, the mean derived from the 16 stands of forests in Peninsular Malaysia, with the significance just missing the 1 per cent level. The Bukit Timah clusters have included 4 stands known to have disturbed or man made forest, viz. Clusters 25, 26, 36 and 37. Even if we exclude these from the t-Test, the conclusion is still the same.

Table 2. Stands of Disturbed or Man-made Forests. (All trees with gbh>=24 inches. See girth size equivalents in Section III(d)).

(a) Cluster 25 with *Adinandra dumosa* as the dominant species

| Species | G1 | G2 | G3 | G4 | G5 | G6 | Total |
|---|---|---|---|---|---|---|---|
| 1. Adinandra dumosa | 0 | 0 | 30 | 6 | 2 | 0 | 38 |
| 2. Campnosperma auriculatum | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| 3. Cratoxylon formosum | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| 4. Gironniera parvifolia | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| 5. Ixonanthes reticulata | 0 | 0 | 1 | 1 | 2 | 1 | 5 |
| 6. Rhodamnia cinerea (R. trinervia) | 0 | 0 | 4 | 1 | 0 | 0 | 5 |
| 7. Timonius wallichianus | 0 | 0 | 2 | 0 | 0 | 0 | 2 |

(b) Cluster 26 also with *Adinandra dumosa* as the dominant species

| Species | G1 | G2 | G3 | G4 | G5 | G6 | Total |
|---|---|---|---|---|---|---|---|
| 1. Adinandra dumosa | 0 | 0 | 18 | 3 | 0 | 0 | 21 |
| 2. Cratoxylon formosum | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 3. Eugenia linocieroidea | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| 4. Ixonanthes reticulata | 0 | 0 | 0 | 0 | 2 | 3 | 5 |
| 5. Ploiarium alternifolium | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| 6. Rhodamnia cinerea (R. trinervia) | 0 | 0 | 3 | 0 | 0 | 0 | 3 |
| 7. Streblus elongatus (Sloetia elongata) | 0 | 0 | 0 | 0 | 1 | 0 | 1 |

(c) Cluster 36 with *Palaquium gutta* as the dominant species

| Species | G1 | G2 | G3 | G4 | G5 | G6 | Total |
|---|---|---|---|---|---|---|---|
| 1. Actinodaphne sesquipedalis | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| 2. Artocarpus scortechinii | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| 3. Litsea elliptica | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| 4. Palaquium gutta | 0 | 0 | 4 | 6 | 5 | 3 | 18 |
| 5. Pellacalyx saccardianus | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| 6. Pimelodendron griffithianum | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| 7. Shorea leprosula | 0 | 0 | 0 | 0 | 1 | 0 | 1 |

(d) Cluster 37 also with *Palaquium gutta* as the dominant species

| Species | G1 | G2 | G3 | G4 | G5 | G6 | Total |
|---|---|---|---|---|---|---|---|
| 1. Adinandra dumosa | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| 2. Antidesma coriaceum | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| 3. Campnosperma auriculatum | 0 | 0 | 0 | 1 | 0 | 1 | 2 |
| 4. Cratoxylon formosum | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| 5. Dysoxylon sp. | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| 6. Eugenia linocieroidea | 0 | 0 | 4 | 0 | 0 | 0 | 4 |
| 7. Gymnacranthera forbesii | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| 8. Gynotroches axillaris | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| 9. Ixonanthes reticulata | 0 | 0 | 1 | 1 | 0 | 1 | 3 |
| 10. Litsea elliptica | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| 11. Gluta wallichii (Melanorrhoea woodsiana) | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| 12. Palaquium gutta | 0 | 0 | 7 | 7 | 1 | 3 | 18 |
| 13. Rhodamnia cinerea (R. trinervia) | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| 14. Sindora sp. | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

It is, however, difficult to proffer an explanation as to why there should be a significant difference. One is tempted to surmise the forest at Bukit Timah is not that primary after all and that past creaming of the forest for small timbers by villagers living in the vicinities could have reduced the density.

Coming to the *Mischungsquotients* in Column 5 of Table 1(a), if we leave out the ones for clusters 25, 26, 36 and 37 for the time being, then we have them ranging from 1.0 to 2.0. If the quotient is 1 then it is the same as saying that within the particular stand every individual belongs to a different species! If it is 2 then we would expect to find two individuals to every species. From the figures we have it can be seen that the Bukit Timah high forest is very mixed and this is comparable to stands found in different parts of Peninsular Malaysia. Figures given by Wyatt-Smith (1963) for Pangkor F.R. Banang F.R., Bukit Lagong F.R. and Kampong Gajah F.R. also range from 1.3 to 1.9.

The quotients for Clusters 25, 26, 36 and 37 are certainly larger than that of the other clusters. As stated earlier large values indicate stands dominated by a few species. Reference to Table 2 will show that this is the case. Clusters 25 and 26 are dominated by a single species, *Adinandra dumosa.* These two stands are in disturbed forest lying at the fringe of the reserve and undergoing succession. Clusters 36 and 37 are dominated by *Palaquium gutta,* a species of commercial importance in the past because it yielded gutta percha, the raw material for chewing gum. Corner (1952) made passing reference to the trees planted in the Taban Valley and Clusters 36 and 37 were located therein.

In rain forest ecology one of the rather intriguing questions is how big a sample one must take in order to include most of the species in an area under investigation. One method employed to get some idea is the Species/Area Curve. Greig-Smith (1964) states that there are commonly three ways in which to construct such a curve, the most efficient being to take independent samples of different sizes within the study area and then plot number of species encountered against area of the respective sample. In this study of ours it was realised from the start that our sample size would never be able to exhaust all the tree species in Bukit Timah, bearing in mind that it has been variously estimated that in Peninsular Malaysia alone there are no less than 3,000 species of trees with 12 inches girth and larger. However, as a look-see exercise a plot is made here (Fig. 3) of species against area, the area of successive classes being cumulative upon the previous total, a method described by Greig-Smith (ibid) as being most inefficient.

Initial attempts to construct the curve included all 20 clusters and it produced a curve that seemed to rise in three steps. This was due to the fact that the four disturbed/man-made stands (see Table 2) mentioned previously, had few species and when the curve hit those stands, it flattened out, only to rise again when it hit again normal stands with more species. As it would not be logical to have a curve covering different known forest types, with obviously different specific composition, the four abnormal stands were taken out and another curve constructed. The resultant curve is shown in Fig. 3. It is noted that it is a relatively smooth curve with the initial portion (within the first 0.8 acre) rising steeply as expected; it then assumes a slightly more gradual slope but right till the end it is still on the rise, showing that our sample of 6.4 acres is far from having included most of the species.

### *(b) Specific Composition of the Forest*

A complete list of species by families arranged in alphabetical order is given in Appendix 1(a). The "unknown" plants are those which we could not identify at all and these are distributed in 13 of the clusters.

Quantitative plant ecological work in the Region has been in progress in the past few decades, during which taxonomic revisions of the various families or genera,

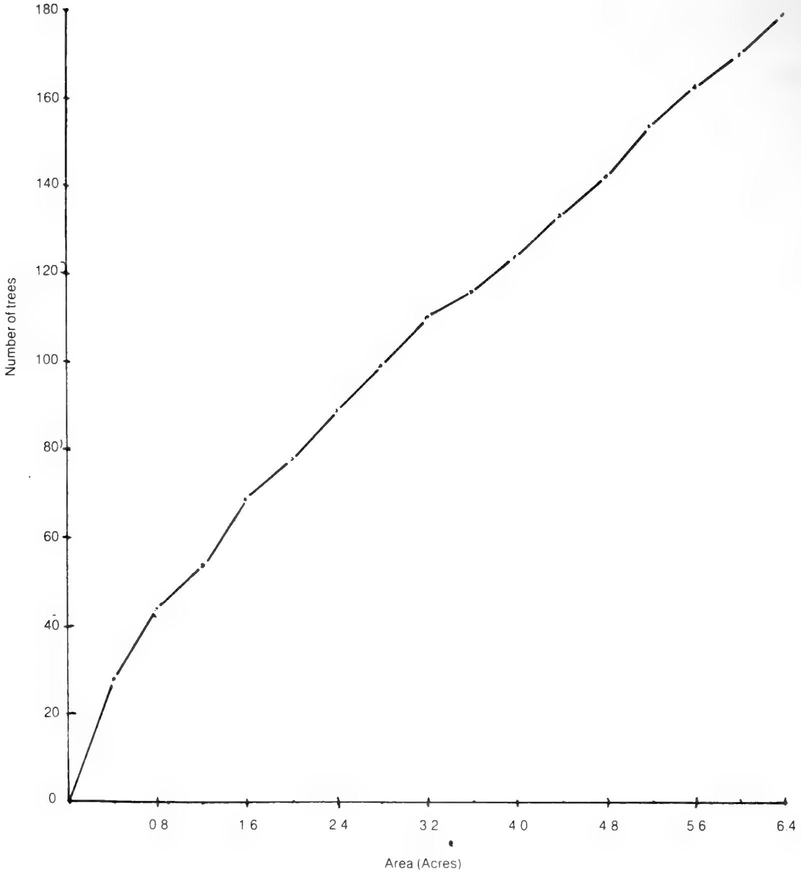


Fig. 3. Species/Area Curve. All trees with gbh>=24 inches.

notably by the Flora Malesiana Foundation, have also taken place. This has rendered some of the familiar and much used Latin names obsolete. In this study, not only have the identities of the plants been checked by the Singapore Botanic Gardens Herbarium, various relevant works have also been consulted to ensure the use of the latest Latin names. However, in order to enable foresters and plant ecologists of the Region, who might not have up-to-date knowledge of the plant names but are nevertheless familiar with old names, to get a quick mental comparison on what they read, I have wherever possible included such names in parentheses after the latest Latin names. This is done in both text and tables.

Appendix 1(b) gives a summary of the number of species and genera by family, with the families arranged in order of species preponderence. There are 44 known families and the totals show that the survey encountered 111 genera, 212 species and 889 individual trees. Apart from the 20 "unknown" trees there are another 20 trees in 11 genera which could be identified down to genus level only. That makes 849 trees which have been fully identified.

It can be seen that Euphorbiaceae has the highest number of genera (11) and the highest number of species (22). In terms of species preponderence the Burseraceae, Dipterocarpaceae, Myrtaceae and Lauraceae all tie second place with 13 species each! Next come Leguminosae with 11 species and Annonaceae with 10 species, and so on.

In terms of sample total the Dipterocarpaceae, with 125 individuals, tops the list. There is an anomaly in that the Theaceae takes second place with a sample total of 94 individuals. The species responsible for this is *Adinandra dumosa,* coming mainly from two clusters located in disturbed forest, namely clusters 25 and 26 (see Table 2). Surprisingly, the Sapotaceae also occupies a position of eminence, 5th in the list. This is due in the main to the fact that clusters 36 and 37 were located in a stand of planted *Palaquium gutta.* If we exclude these 4 stands from the analysis, then the two families in question would go further down in the list.

Barring the anomaly created by the 4 stands just referred to, one could say that the specific composition as encountered in Bukit Timah in the undisturbed stands is quite typical of the Lowland Dipterocarp Forest, of which the Coastal Hill Forest may be considered as a sub-type. As mentioned earlier, one of the outstanding features of the Coastal Hill Forest is the presence of *Shorea curtisii* (Seraya) at low elevation. In Bukit Timah its occurrence could be as low as 150 ft a.s.l. Associated with Seraya are usually such species as *Shorea gratissima, Shorea glauca, Dipterocarpus caudatus* ssp. *penangianus (D. penangianus) Anisoptera curtisii, Artocarpus lanceifolius, Swintonia schwenkii* or *S. spicifera.* With the exception of *Shorea glauca* these species are found within Bukit Timah but *Anisoptera curtisii* and *Swintonia* have not been netted in by our sample.

The dipterocarps have in this study shown family dominance, a fact which is quite well known from various studies made in Malaysia. In the Bukit Timah case this dominance is very much the result of two dipterocarp species, viz *Shorea curtisii,* with a total of 46 individuals, and *Dipterocarpus caudatus* ssp. *penangianus (D. penangianus)* with 37 individuals. These two dipterocarps alone have contributed 83 individuals out of a total of 125 (vide Appendix 1(a) & the end of Appendix 4).

Looking at Appendix 1(b) if we remove the two clusters located in the secondary forest dominated by *Adinandra dumosa,* then we would have the Euphorbiaceae taking the second place with a total of 70 individuals. It also has a preponderance of genera and species — with respectively 11 and 22 numbers. In terms of species, the genera *Aporusa* and *Baccaurea* contribute most to the total number. *Baccaurea kunstleri* and *Pimelodendron griffithianum* seem to be quite common and widespread. Unlike the dipterocarps, however, trees of the Euphorbiaceae are small. Even the larger ones have their crowns in the Main Storey of the canopy and many of them stay in the C storey. In our sample, probably the largest trees are *Endospermum diadenum (E. malaccense) Blumeodendron tokbrai* and *Baccaurea kunstleri,* all growing up to about 70 ft.

The Anacardiaceae follows closely behind the Euphorbiaceae in the preponderance of individuals with a sample total of 58, coming mainly from two species, viz *Gluta wallichii (Melanorrhoea woodsiana)* and *Campnosperma auriculatum,* respectively with 34 and 16 individuals. In Bukit Timah, it is somewhat surprising that the genus *Mangifera* is not as common as it should be. *Mangifera lagenifera,* for example, just like *Swintonia schwenkii,* is seen sporadically only in the Reserve, but our sample has not been able to net it in.

*Campnosperma auriculatum* is an interesting species in that it has a very wide ecological amplitude. It occurs in both primary and secondary forests, in the lowlands, in mountains and in the peat and fresh water swamps! Such a feat seems to be equalled only by *Koompassia malaccensis*(Leguminosae). In Bukit Timah, as in other places with high forest nearby *C. auriculatum* is one of the first pioneers to colonise secondary vegetation and in the primary jungles it can grow to a large emergent.

*Gluta wallichii (Melanorrhoea woodsiana),* apart from being abundant, is also the most wide spread species in Bukit Timah as the Distribution Index (see next

Section) will show, much to the woe of those who are allergic to its potent skin irritant! *Gluta wallichii,* unlike *Campnosperma,* is not a very large tree. Even when full grown its crown would be in the Main Storey of the canopy.

For more information on the relative importance of the various families and species in our sample, the reader is referred to the various parts of Appendix 1.

### *(c) Spatial Distribution of Species and the Distribution Index (DI)*

From the *Mischungsquotient* mentioned earlier, it can be seen that the Bukit Timah forest, just like other Rain Forests in the Region, has a great diversity of species. Yet there can be no doubt that some species are of very low density while others show considerable dominance in numbers. Some species are vagrant while others tend to be more gregarious. In such a situation tabulation to show the presence of a species would not be too meaningful if we give only its sample total for it could mean that the individuals were present in only one or two sampling units, or they might be spread over many units. Because of this it is thought much more useful to present a comprehensive list of the plants showing both their sample totals as well as the extent to which they spread over the entire sample.

To show the latter phenomenon a parameter called the Distribution Index (DI) is used. The DI of a species is simply the number of sampling units in which it occurs. Thus, for example, in Appendix 1(a) it is seen that *Dipterocarpus caudatus* ssp. *penangianus (D. penangianus)* has a DI of 12. It simply means that in the whole sample, it occurs in 12 of the 20 clusters.

It has to be noted that it does not matter how many individuals occur in a cluster. So long as there is one individual of the species, the species scores 1 for that particular sampling unit. On the other hand even if there are 10 individuals in the unit the score for DI is still 1. This brings us to the other point which is important

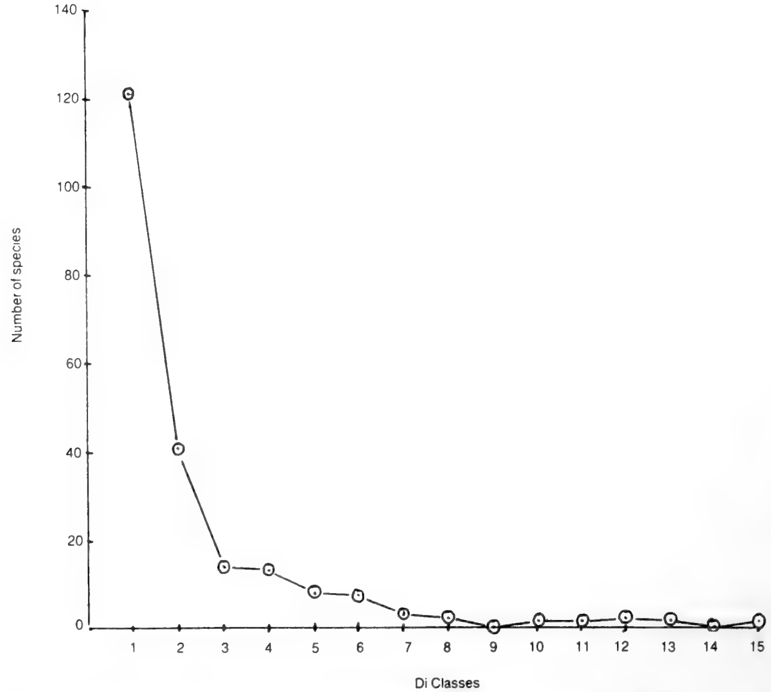


Fig. 4. Species Distribution & Distribution Index (DI). (See Section III(c) of text.)

for showing dominance, i.e. the sample total of a particular species. Taking *D. caudatus* ssp. *penangianus* again as an example, we find that its sample total from all the clusters adds up to 37. This is indeed a very high number compared with many other species. This, coupled with the fact that it is distributed in 12 of the 20 clusters, shows that it is wielding considerable influence within the community we have sampled.

Appendix 1(a) shows the DI amongst other things but much more information could be got at a glance by referring to Appendix 2. In here both sample total and the DI of a species are given with the DI indexed in ascending order. From here it can be seen that more than half of the species occur only once whereas others may occur in one cluster only but within that cluster it occurs 5 times. Such is the case with for example *Aporusa bracteosa* (Euphorbiaceae). Further, it can be seen that as DI increases the number of species drops rapidly (see Fig. 4). There are 121 species with DI=1 but when DI 7 is reached, there are only 3! These are *Pimelodendron griffithianum, Streblus elongatus (Sloetia elongata)* and *Timonius wallichianus.* Of the known species only 5 score a DI equal to or greater than 10. They are *Pellacalyx saccardianus* (10), *Artocarpus lanceifolius* (11), *Dipterocarpus caudatus* ssp. *penangianus* (12), *Shorea curtisii* (12) and *Gluta wallichii (Melanorrhoea woodsiana)* (15).

Species which have a DI of unity and small total, say 1 or 2 are likely to be isolated vagrants while those with a high DI and high total are the really common species of the community. A third condition can be that a species may have a low DI but a very high total. Such a case indicates an extremely gregarious condition and this may reflect the successional status of the particular community. Browsing through Appendix 2 one could discern such a condition for *Campnosperma auriculatum* (TOT 16, DI 3) *Rhodamnia cinerea (R. trinervia)* (TOT 16, DI 3) *Adinandra dumosa* (TOT 90, DI 4) *Palaquium gutta* (TOT 38, DI 4). In the case of *Campnosperma,* the master list (not included in this report) reveals that most of the individuals (some 11 numbers) come from Cluster 32 alone. Inspection of the list of species for the cluster shows that the associated species within that particular cluster are matured individuals of high forest species. But a closer scrutiny reveals that some 8 trees occur in Plot B alone within that cluster. It is therefore certain that Cluster 32 had been placed straddling the boundary between high and regenerating (disturbed) forest.

In the case of *Rhodamnia* and *Adinandra* most of the individuals have come from Clusters 25 and 26, which are located in disturbed vegetation. *Palaquium gutta,* as indicated previously, comes mainly from the historical planted patch within the Taban Valley.

### *(d) Structure of the Forest and Recruitment*

For forest structure we shall use girth class distribution as an indicator. Appendix 2, *inter alia,* gives the girth class distribution of the various species and individuals encountered, from G1 to G6. The equivalents in inches are given below:

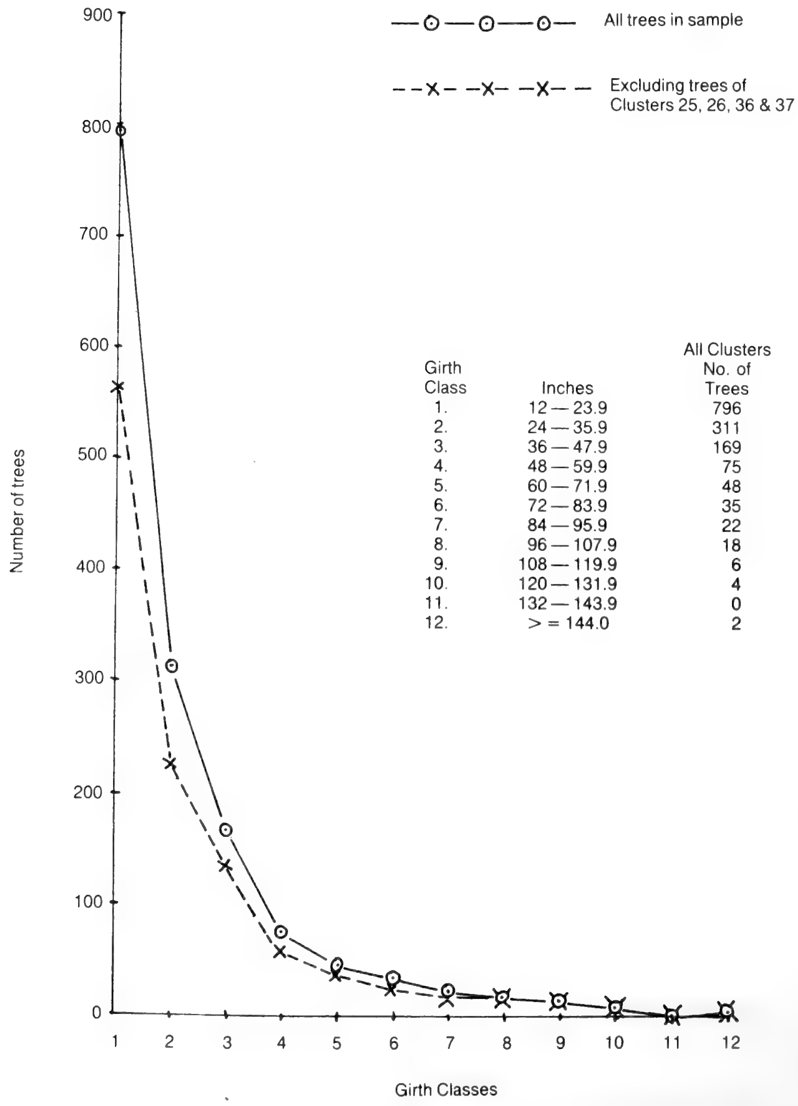
| G1 | G2 | G3 | G4 | G5 | G6 |
|---|---|---|---|---|---|
| 12-12.9 | 13-23.9 | 24-35.9 | 36-47.9 | 48-59.9 | >=60.0 |

As mentioned in the notes on enumeration, G1 and G2 were only measured in the sub-sample of Plot A in each cluster. Appendix 2 has included all individuals down to G1.

Girth classes in a gigantic table are difficult to visualise. On account of this a graph is produced by plotting number of trees against girth classes. Before doing so the data were re-arranged so that the girth classes extend from 12 inches gbh to over 144 inches gbh. As the 12-24 inch girth class was measured only in one of four sub-plots, the number obtained was extrapolated by multiplying by 4 so as to bring it in line with the other girth classes. The value of Girth Class 1 in Fig. 5 (796) has been obtained in this way.

The graph in Fig. 5 shows a typical inverted "J" for girth class distribution of individuals in a stand of uneven-aged forest. The characteristics are a very high number of small trees and a low number of very large trees.

The graph suggests that the forest as a whole is well stocked with young trees to take the place of the big giants when they die. This interpretation is likely to be an over-simplification. As is already known the forest is extremely mixed. The ecosystem is likely to be controlled by a fairly large number of species. For the present forest to beget a similar forest in the future, it is necessary to have species that form a large proportion of the present composition and which have vertical distribution



| Girth Class | Inches | All Clusters No. of Trees |
|---|---|---|
| 1. | 12 — 23.9 | 796 |
| 2. | 24 — 35.9 | 311 |
| 3. | 36 — 47.9 | 169 |
| 4. | 48 — 59.9 | 75 |
| 5. | 60 — 71.9 | 48 |
| 6. | 72 — 83.9 | 35 |
| 7. | 84 — 95.9 | 22 |
| 8. | 96 — 107.9 | 18 |
| 9. | 108 — 119.9 | 6 |
| 10. | 120 — 131.9 | 4 |
| 11. | 132 — 143.9 | 0 |
| 12. | > = 144.0 | 2 |

Fig. 5. Frequency Distribution in Different Girth Classes.

over the whole range of canopy strata. The data presented in the various sections in Appendix 3 are meant to afford a glimpse into this problem.

Each section presents the results of a command put to the computer to list the species with a definite girth class distribution pattern. In App. 3:a it was asked to display species which are represented in all girth classes. Only one species, *viz Streblus elongatus (Sloetia elongata)* met the condition. This species is likely to survive well under even adverse conditions. Not only does it have a high total, it also has a fairly high DI of 7, showing that it is fairly widely distributed. Indeed it is common knowledge that this species occurs in all kinds of vegetation and is one of the pioneers in regenerating forests.

App. 3:b lists species which have a continuous girth class distribution from G2 through to G6. For this 9 species meet the condition, including *Streblus* (*Sloetia*). It is interesting to note that practically all the species are high forest species and they are components of the different canopy strata — *Shorea curtisii, Dipterocarpus caudatus ssp. penangianus* and *Campnosperma auriculatum* are emergents; *Artocarpus lanceifolius, Gluta wallichii (Melanorrhoea woodsiana)* and *Artocarpus rigidus* are Main Storey species while the others are C-storey or Main Storey species. Moreover, for all of them G2+G3 are very strongly represented. These are trees with gbh from 13 inches to 36 inches. These are most likely to grow to maturity to take over from the present giants. There is yet another plus factor for this group of species, for it may be recalled that G1 & G2 were obtained using only 1 circular plot. Conceivably their numbers are much larger if we had sampled down to G1 in all the circular plots.

The total number of individuals in this group of trees number 241. Since *Palaquium gutta* comes from the planted plot we exclude its individuals. With this, 203 trees remain. The grand total for the whole sample is 889 trees. Taking proportion we can see that these few species contribute to over 22% of the total population. Not only that, with the exception of *Palaquium* and *Campnosperma,* they also have high DI's, indicating that they are widespread. They therefore exert considerable structural and other ecological influence on the community.

For App. 3:d the display is of species with a continuous girth class distribution from G4 to G6 and for this two more dipterocarps which are emergents and several more Main Storey species are included. Here we can discern species, *Shorea macroptera* and *Palaquium hexandrum,* which do not have small trees and we are apt to jump to the conclusion that they therefore lack a vital factor to back up their succession. However, this may not be necessarily so and this question is discussed further in the next Section.

## IV. Discussion

The present study has confirmed that the forest at Bukit Timah Nature Reserve should best be considered as a Coastal Hill Forest according to Symington's classification (vide 1942, ibid) and as far as one could see a large proportion of the forest is still of a primary nature. However, although there was no organised commercial logging of the forest for timber, the significantly lower density of the forest compared with some stands in such a forest type in West Malaysia, gives rise to speculation that removal of small timbers by villagers living nearby could have taken place in the past. The average density of the forest at Bukit Timah is some 16% less than that of the Malaysian stands quoted in Table 1(b).

The forest at Bukit Timah is indeed rich dipterocarp forest with large trees of *Shorea curtisii* (Seraya) *Dipterocarpus caudatus ssp. penangianus* (Keruing) and many other trees of dipterocarps and non-dipterocarps which loggers would salivate over were they to see them in their concession area! Yet these giants seemed to have escaped the saw. To hazard a guess one would say that one reason for their having done so lies perhaps in their not belonging to the groups of naturally durable heavy hardwood which loggers in the early days of timber utilisation sought after. Most of the large and common trees in Bukit Timah would yield what the wood technologist would classify as light or medium hardwood which found extensive uses only after the War on account of advancement in wood preservation. By that time, fortunately, Bukit Timah was already a nature reserve.

According to Symington, Coastal Hill Forest communities should have quite a number of Balaus (the Heavy Hardwood dipterocarps) such as *Shorea glauca* and *S. maxwelliana*. These, however, have not been met with during our enumeration nor did the writer see any outside the sample. Could their absence be due to past creaming? This is difficult to say but is unlikely for no sign of stumps could be seen nor would the very natural and undisturbed nature of the environment suggest past logging activities. Further, if such species had been in the forest before then although selective logging would have removed the large trees, their progeny could have survived in the forest and by now would have grown to sizeable individuals. Their absence therefore suggests that the forest is inherently lacking in such species.

Tropical Rain Forests are noted for their diversity of species. The present study shows that the forest at Bukit Timah is no exception. Indeed with *Mischungsquotients* ranging between 1.0 and 2.0 the forest is as diverse as any in Malaysia. Furthermore the stand curve derived has shown that the forest also has girth class distribution typical of uneven-aged stands. The characteristic inverted "J" indicates the presence of a very large number of small trees, quite numerous larger trees and a small number of very large trees.

Despite this, however, one of the nagging questions concerning a small area of forest like Bukit Timah (185 acres) which is completely isolated, is whether it could survive with unchanged character over a long period of time. The analysis in the previous Section has already touched briefly on this subject. Based on the evidence available it would appear quite a number of the high forest species show good recruitment and are well represented in the whole range of girth classes studied. On the other hand many of the giants have big trees only and are completely lacking in smaller progeny. One is apt to jump to the simple conclusion that those with smaller trees in say G1 to G3 are likely to survive while those without such small trees will be in danger of dying out. In actual fact the situation is likely to be much more complex and for a more complete picture, study of the seedling populations and of trees of different size classes of various species, under a continuous inventory with say annual reenumeration to assess changes in the populations, due to normal mortality and recruitment or to catastrophes, with time would be necessary. This of course would entail the laying down of permanent sampling units and labelling of the plants permanently.

The optimist may argue that the forest at Bukit Timah has been there for millennia and it has survived unchanged up to now despite its progressive isolation into a small plot of land in recent times. It is certainly true that based on its present composition, we can conclude that the forest is still similar to any other Coastal Hill Forest. Also even if it is true that species of emergents have no pole-sized trees at any one point in time that does not mean that there would not be such trees at a later date. The seedlings of *Shorea curtisii* (Seraya) are known to be able to grow up under their parents in rather shaded conditions and this may account for its superiority in numbers and continuous girth class distribution over a wide range of girth sizes (vide also Wong (1978)). On the other hand some species are known to have a truncated girth class distribution in nature, over a sizeable area of forest. Some of the emergents, e.g. *Shorea leprosula,* though needing forest conditions for its saplings to grow up, are known to be light demanders and they need an opening in the canopy such as one resulting from the parent tree having been killed by a natural catastrophe, to give them the additional light and or reduction in root competition for growing up. If no disaster occurs over the area of forest in question to create the gaps, for a long, long time, then only large trees will appear in a sample. Poore (1968) has found in a lowland forest of 1 square kilometer in Jengka F.R. in Pahang, Malaysia, that 8 — 10% of the forest was under regeneration in some gaps. Further, he estimated that such gaps would take about 30 years to mature, i.e. to produce uniform crown conditions again to merge with the adjacent trees, and that such regenerated areas could last for a mean period of some 270 years! If this is so then uniform shaded conditions would prevail over this period and it would preclude the possibility of light demanding seedlings/saplings from growing up. It is little wonder therefore such species have a truncated girth class distribution.

The example just considered relates to a case of the habitat being taken over by the progeny of a tree formerly occupying it. However, this need not be always the case. Indeed it is doubtful when a forest dies it would be replaced by its replica. The demise of a big tree or group of trees could create conditions favourable for the progeny of nearby species to develop in the gap so created. It is entirely a matter of chance as to what would seed up, or grow up in, such a gap apart from saplings of the trees formerly occupying the site, as they might be there. Other factors being equal proximity of species to the gaps and an inherently more frequent fruiting habit, would definitely be an advantage. Thereafter the ensuing fierce competition will also determine what would survive and grow up to maturity.

It is most probable that such chanced reproduction of species in regeneration gaps in large ecosystems like the Lowland Dipterocarp Forest and the Peat Swamp Forest, is one way of ensuring species survival and hence species diversity. Enormity of area would ensure superiority in numbers for practically all species and hence a good chance for all to regenerate and survive. Thus although the composition of the forest and the pattern of species distribution may change from generation to generation, the same pool of species will remain practically unchanged.

The same mode of regeneration has been observed to take place in Bukit Timah but in a small isolated community it is likely that the innate ability of the species to regenerate and grow up in shade would be important for perpetuation. Perhaps it is no coincidence that the few species shown in Appendix 3: b have individuals in the whole range of girth class distribution and are numerically dominant as a group. Indeed they are the very species (perhaps with the exception of *Campnosperma*) that possess the innate quality of being able to reproduce and grow up in the shade and in the ambit of the parent trees.

*Shorea curtisii, Anisoptera curtisii, Artocarpus lanceifolius* are essentially Hill Forest species, in inland mountains occurring from about 1000 ft. to 2500 ft. a.s.l. in Malaysia. They miss the vast areas of Lowland Dipterocarp Forest only to emerge again in the Coastal Hills. Coastal Hills in contrast with inland mountain masses are always small. In this respect I would say that the forest at Bukit Timah, at least the typical Coastal Hill species viz *Shorea curtisii, Dipterocarpus caudatus* ssp. *penangianus, Anisoptera curtisii* and to some extent *Artocarpus lanceifolius,* have always faced isolation, even before the advent of Man as they could grow only in the Coastal Hill habitat in Singapore. Presumably the other species which are common to both Lowland Forest and the Coastal Hill Forest could have moved to and fro in geological time, thus contributing to and ensuring the complexity of their kinds; but not the few species just mentioned as they could only grow in the Hills. Granted that places like Mt Faber, Bukit Gombak and some of the hills in the Pasir Laba area, could have carried Coastal Hill species, knowing their characteristics they could not have migrated to and fro to maintain their dominance in these places. In other words these species must have persisted as isolated colonies, and their innate ability to regenerate and grow up in the shade has ensured their survival and dominance.

Looked upon in this light it is likely that these species that wield structural dominance and to some extent numerical dominance (when considered as a group) would be able to persist in perpetuity, provided of course Bukit Timah is preserved. However, the physical isolation resulting from recent road and other development could induce more drastic fluctuations in the critically important ecological factors such as temperature and humidity. These may affect the periphery more but by and large they are not likely to have much effect on the interior of the Reserve bearing in mind that we are in the heart of the Humid Tropics. One thing though we must guard against and that is the danger of fire. During a very dry year the scrubland on the periphery may catch fire and this may cause destruction to the dried up interior of the forest. Such an event actually happened to Cape Rachado, another Coastal Hill Forest situated about 10 miles south of Port Dickson. The forest was badly burnt when it caught fire during the unusually dry spell of 1963. Many of the giant shoreas were killed and the place was invaded by *Trema* spp. For the other species on Bukit Timah which are common to both the Lowland Forest and the Coastal Hill Forest, particularly those with low frequencies and small DI's, the diminutive state of the Reserve does give cause for concern. For such species, the timing of a seed year or the presence of seedlings or small trees and the chance demise of the parent tree is very critical. This is particularly so when it is realised that most of the large trees in the Rain Forest have evolved with long fruiting intervals of 2, 3 and as long as, 7 years. For a small, isolated forest like Bukit Timah the scenario as depicted below could happen.

Let us say a *Dyera costulata,* the Jelutong, (of which there are only a few individuals in the Reserve) has no seedlings on the ground now. Neither are there pole-sized trees around. It is killed by lightning. That could be the end of that tree and species in that particular spot. Since the Reserve is small and since the population of such a species is finite it is conceivable that after a few more of such disasters, the species is extinct within the Reserve. This is the kind of mechanism that could in the long run lead to retrogressive changes in the specific composition of the forest, resulting in the decline in the number of species. Unlike the geological past, before the advent of Man, there shall not be Jelutong trees near Bukit Timah to effect migration back to it!

To conclude I think we can say that Bukit Timah is unique in that at the fringe of a great metropolis lies the relict of a small Rain Forest community completely isolated by non-forested areas. Ecologically it should be extremely interesting to study. Scientific records obtained under a continuous inventory over the next decade or two should yield preliminary information on changes in the community with its component small animals one way or another. Would it be able to survive with no loss in characteristics or would it degenerate into a secondary forest such as many experts have predicted. Only time and some hard work will tell.

## Acknowledgement

As mentioned in the introduction the field work of the project was carried out as an activity of the Singapore Branch of the Malayan Nature Society. At the time the Secretary was Mrs Lisette Henrey. She and her husband were indeed staunch supporters. This could be seen from the fact that Mr. Henrey had on many occasions come with their toddler kid tied to his back Chinese style to help in the enumeration! Other regular supporters were Prof. A.N. Rao of the Botany Department, University of Singapore, and his colleagues, notably Prof. Hsuan Keng, and

Dr. K.H. Chow, my then colleagues Lee Sing Kong & Teoh Teck Seng, and students of the Ornamental School of Horticulture, Botanic Gardens. Occasionally we were also joined by some other members of the Malayan Nature Society of whom it will be too numerous to mention by names and to whom I should like to express my grateful thanks for having helped in the field work.

I am also very much indebted to Mohd. Shah of the Botanic Gardens for having assisted in the identification of materials in the herbarium. If not for his painstaking work the magnitude of the "Unknown" in our plant lists would have been much larger. He and Ali Ibrahim also helped to up-date the Latin names of many of the species and the authorities that go with them.

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## Appendix 1: a. Complete list of species (gbh>=12") by family, with the species' sample totals and their distribution indices (DI).

(For explanation on DI see text Sect. III (c). Latin names in parentheses are obsolete but familiar names.)

| Rec.# | Family | Species | Total | DI |
|---|---|---|---|---|
| 1. | ANACAR | Bouea macrophylla Griff. | 1 | 1 |
| 2. | ANACAR | Bouea oppositifolia (Roxb.) Meissn. | 1 | 1 |
| 3. | ANACAR | Buchanania sessilifolia Bl. | 2 | 2 |
| 4. | ANACAR | Campnosperma auriculatum (Bl.) Hk. f. | 16 | 3 |
| 5. | ANACAR | Gluta wallichii (Hk. f.) Ding Hou<br>(Melanorrhoea woodsiana King) | 34 | 15 |
| 6. | ANACAR | Parishia paucijuga Engl. | 4 | 4 |
| 7. | ANONA | Anaxagorea javanica Bl. | 1 | 1 |
| 8. | ANONA | Cyathocalyx ramuliflorus (Maing. ex Hk. f & Th.) Scheff. | 7 | 6 |
| 9. | ANONA | Cyathocalyx ridleyi (King) Sinclair | 1 | 1 |
| 10. | ANONA | Fissistigma lanuginosum Hk. f. et Th. | 2 | 1 |
| 11. | ANONA | Fissistigma latifolium (Duval) Merr. | 1 | 1 |
| 12. | ANONA | Polyalthia hookeriana King | 1 | 1 |
| 13. | ANONA | Polyalthia rumphii (Bl.) Merr. | 2 | 1 |
| 14. | ANONA | Polyalthia sp. | 2 | 1 |
| 15. | ANONA | Xylopia ferruginea (Hk. f. et Th.) Hk. f. et Th. | 1 | 1 |
| 16. | ANONA | Xylopia malayana Hk. f. et Th. | 2 | 2 |
| 17. | APOCYN | Alstonia angustifolia Wall. ex A.DC. | 1 | 1 |
| 18. | APOCYN | Dyera costulata (Miq.) Hk. f. | 1 | 1 |
| 19. | BOMBAC | Durio griffithii (Mast.) Bakh. | 1 | 1 |
| 20. | BURSER | Canarium grandifolium (Ridl.) H.J. Lam | 1 | 1 |
| 21. | BURSER | Canarium sp. | 1 | 1 |
| 22. | BURSER | Dacryodes costata (Benn.) H.J. Lam | 2 | 1 |
| 23. | BURSER | Dacryodes laxa var typica (Benn.) H.J. Lam | 2 | 2 |
| 24. | BURSER | Dacryodes rostrata (Bl.) H.J. Lam | 2 | 2 |
| 25. | BURSER | Dacryodes rugosa (Bl.) H.J. Lam | 1 | 1 |
| 26. | BURSER | Santiria apiculata Benn. | 2 | 1 |
| 27. | BURSER | Santiria griffithii (Hk. f.) Engl. | 12 | 8 |
| 28. | BURSER | Santiria laevigata Bl. | 8 | 8 |
| 29. | BURSER | Santiria rubiginosa Bl. | 5 | 4 |
| 30. | BURSER | Santiria tomentosa Bl. | 3 | 2 |
| 31. | BURSER | Santiria sp. A | 1 | 1 |
| 32. | BURSER | Santiria sp. B | 1 | 1 |
| 33. | CELAST | Bhesa paniculata Arn. | 4 | 2 |
| 34. | CELAST | Kokoona reflexa (Laws.) Ding Hou<br>(Lophopetalum reflexum Laws.) | 1 | 1 |
| 35. | CONNAR | Agelaea borneensis (Hk. f.) Merr. | 1 | 1 |
| 36. | CONNAR | Ellipanthus tomentosus kurz | 1 | 1 |
| 37. | DILLEN | Dillenia grandifolia Wall. ex Hk. f. et Th.<br>(Dillenia eximia Miq.) | 2 | 2 |
| 38. | DIPTER | Anisoptera costata Korth. | 1 | 1 |
| 39. | DIPTER | Dipterocarpus kerrii king | 5 | 3 |
| 40. | DIPTER | Dipterocarpus caudatus ssp. penangianus (Foxw.) Ashton<br>(Dipterocarpus penangianus Foxw.) | 37 | 12 |
| 41. | DIPTER | Dipterocarpus sublamellatus Foxw. | 3 | 1 |
| 42. | DIPTER | Hopea mengarawan Miq. | 4 | 4 |

(Appendix 1:a cont.)

| Rec.# | Family | Species | Total | DI |
|---|---|---|---|---|
| 43. | DIPTER | Shorea bracteolata Dyer | 1 | 1 |
| 44. | DIPTER | Shorea curtisii Dyer ex King | 46 | 12 |
| 45. | DIPTER | Shorea gratissima (Wall. ex Kurz.) Dyer | 3 | 2 |
| 46. | DIPTER | Shorea leprosula Miq. | 10 | 5 |
| 47. | DIPTER | Shorea macroptera Dyer | 4 | 3 |
| 48. | DIPTER | Shorea pauciflora King | 9 | 6 |
| 49. | DIPTER | Vatica maingayi Dyer | 1 | 1 |
| 50. | DIPTER | Vatica sp. A | 1 | 1 |
| 51. | EBENA | Diospyros buxifolia (Bl.) Hiern | 2 | 2 |
| 52. | EBENA | Diospyros lanceifolia Roxb. | 1 | 1 |
| 53. | EBENA | Diospyros maingayi (Hiern) Bakh. | 1 | 1 |
| 54. | EBENA | Diospyros sp. | 1 | 1 |
| 55. | ELAEOC | Elaeocarpus acronodia Bl.<br>(Elaeocarpus mastersii King) | 2 | 2 |
| 56. | ELAEOC | Elaeocarpus nitidus Jack | 2 | 1 |
| 57. | ELAEOC | Elaeocarpus petiolatus Wall. | 1 | 1 |
| 58. | ELAEOC | Elaeocarpus polystachyus Wall. | 1 | 1 |
| 59. | EUPHOR | Antidesma coriaceum Tul. | 3 | 3 |
| 60. | EUPHOR | Antidesma cuspidatum Muell. Arg. | 1 | 1 |
| 61. | EUPHOR | Aporusa benthamiana Hk. f. | 2 | 2 |
| 62. | EUPHOR | Aporusa bracteosa Pax. et Hoffm. | 5 | 1 |
| 63. | EUPHOR | Aporusa prainiana King ex Gage | 1 | 1 |
| 64. | EUPHOR | Aporusa sp. A | 1 | 1 |
| 65. | EUPHOR | Aporusa sp. B | 1 | 1 |
| 66. | EUPHOR | Baccaurea bracteata Muell. Arg. | 2 | 2 |
| 67. | EUPHOR | Baccaurea kunstleri King ex Gage | 9 | 5 |
| 68. | EUPHOR | Baccaurea maingayi Hk. f. | 2 | 2 |
| 69. | EUPHOR | Baccaurea sumatrana Miq. | 6 | 5 |
| 70. | EUPHOR | Baccaurea sp. A | 2 | 2 |
| 71. | EUPHOR | Baccaurea sp. B | 1 | 1 |
| 72. | EUPHOR | Blumeodendron tokbrai (Bl.) Kurz | 5 | 4 |
| 73. | EUPHOR | Elateriospermum tapos Bl. | 2 | 2 |
| 74. | EUPHOR | Endospermum diadenum (Miq.) Airy Shaw<br>(Endospermum malaccense Muell. Arg.) | 4 | 4 |
| 75. | EUPHOR | Koilodepas longifolium Hk. f. | 1 | 1 |
| 76. | EUPHOR | Macaranga conifera (Zoll.) Muell. Arg. | 2 | 1 |
| 77. | EUPHOR | Macaranga lowii King ex Hk. f. | 1 | 1 |
| 78. | EUPHOR | Mallotus penangensis Muell. Arg. | 5 | 1 |
| 79. | EUPHOR | Pimelodendron griffithianum (Muell. Arg.) Benth. | 9 | 7 |
| 80. | EUPHOR | Ptychopyxis caput-medusae (Hk. f.) Ridl. | 5 | 2 |
| 81. | FAGA | Castanopsis megacarpa Gamb. | 1 | 1 |
| 82. | FAGA | Castanopsis wallichii King ex Hk. f. | 1 | 1 |
| 83. | FAGA | Castanopsis sp. | 1 | 1 |
| 84. | FAGA | Lithocarpus conocarpus (Oudem.) Rehd. | 2 | 2 |
| 85. | FAGA | Lithocarpus encleisacarpus (Korth) A. Camus | 3 | 3 |
| 86. | FAGA | Lithocarpus ewyckii (Korth) Rehd. | 2 | 1 |
| 87. | GUTTIF | Calophyllum curtisii King | 3 | 2 |
| 88. | GUTTIF | Calophyllum ferrugineum Ridl. | 4 | 4 |
| 89. | GUTTIF | Calophyllum pulcherrimum Wall. ex Planch. et Triana | 4 | 3 |
| 90. | GUTTIF | Calophyllum rubiginosum Hend. et Wyatt-Smith | 2 | 1 |

*(Appendix 1:a cont.)*

| Rec.# | Family | Species | Total | DI |
|---|---|---|---|---|
| 91. | GUTTIF | Calophyllum wallichianum Planch. et Triana | 1 | 1 |
| 92. | GUTTIF | Garcinia hombroniana Pierre | 2 | 2 |
| 93. | GUTTIF | Garcinia nigrolineata Planch. et T. Anders. | 2 | 2 |
| 94. | GUTTIF | Garcinia rostrata (Hassk.) Miq. | 1 | 1 |
| 95. | HYPERI | Cratoxylon formosum (Jack) Dyer | 3 | 3 |
| 96. | IXONAN | Ixonanthes icosandra Jack | 4 | 4 |
| 97. | IXONAN | Ixonanthes reticulata Jack | 20 | 6 |
| 98. | LAURA | Actinodaphne malaccensis Hk. f. | 1 | 1 |
| 99. | LAURA | Actinodaphne sesquipedalis Hk. f. et Th. ex Meissn. | 1 | 1 |
| 100. | LAURA | Beilschmiedia maingayi Hk.f. | 3 | 3 |
| 101. | LAURA | Cinnamomum zeylanicum Garc. ex Bl. | 1 | 1 |
| 102. | LAURA | Cryptocarya ferrea Bl. | 1 | 1 |
| 103. | LAURA | Crytocarya rugulosa Hk. f. | 1 | 1 |
| 104. | LAURA | Litsea castanea Hk. f. | 8 | 5 |
| 105. | LAURA | Litsea costalis (Bl.) Kosterm. | 1 | 1 |
| 106. | LAURA | Litsea elliptica Bl. | 3 | 3 |
| 107. | LAURA | Litsea gracilipes Hk. f. | 1 | 1 |
| 108. | LAURA | Litsea grandis Hk. f. | 2 | 1 |
| 109. | LAURA | Litsea machilifolia Gamb. | 2 | 2 |
| 110. | LAURA | Nothaphoebe umbelliflora (Bl.) Bl. | 1 | 1 |
| 111. | LEGUMI | Dialum kingii Prain. | 4 | 3 |
| 112. | LEGUMI | Dialium laurinum Baker | 2 | 2 |
| 113. | LEGUMI | Dialium maingayi Baker | 1 | 1 |
| 114. | LEGUMI | Dialium patens Baker | 2 | 1 |
| 115. | LEGUMI | Dialium platysepalum Baker | 3 | 1 |
| 116. | LEGUMI | Dialium wallichii Prain | 2 | 1 |
| 117. | LEGUMI | Koompassia malaccensis Maing. ex Benth. | 10 | 6 |
| 118. | LEGUMI | Sindora coriacea Maing. ex Prain | 1 | 1 |
| 119. | LEGUMI | Sindora echinocalyx (Benth.) Prain | 1 | 1 |
| 120. | LEGUMI | Sindora velutina Baker | 1 | 1 |
| 121. | LEGUMI | Sindora sp. | 1 | 1 |
| 122. | MAGNOL | Aromadendron elegans Bl. | 2 | 2 |
| 123. | MELAST | Memecylon coeruleum Jack | 1 | 1 |
| 124. | MELAST | Pternandra coerulescens Jack | 2 | 2 |
| 125. | MELAST | Pternandra echinata Jack | 7 | 5 |
| 126. | MELIA | Aglaia trichostemon C. DC. | 2 | 2 |
| 127. | MELIA | Aglaia sp. | 2 | 2 |
| 128. | MELIA | Chisocheton erythrocarpus Hiern. | 1 | 1 |
| 129. | MELIA | Dysoxylon sp. | 5 | 1 |
| 130. | MELIA | Sandoricum koetjape (Burm. f.) Merr. | 1 | 1 |
| 131. | MORA | Artocarpus kemando Miq. | 1 | 1 |
| 132. | MORA | Artocarpus lanceifolius Roxb. | 14 | 11 |
| 133. | MORA | Artocarpus rigidus Bl. | 9 | 6 |
| 134. | MORA | Artocarpus scortechinii King | 5 | 4 |
| 135. | MYRIST | Gymnacranthera eugeniifolia (A. DC.) Sincl. | 2 | 2 |
| 136. | MYRIST | Gymnacranthera forbesii (King) Warb. | 1 | 1 |
| 137. | MYRIST | Horsfieldia brachiata (King) Warb. | 1 | 1 |
| 138. | MYRIST | Horsfieldia superba (Hk. f. & Th.) Warb. | 1 | 1 |
| 139. | MYRIST | Knema hookeriana (Hk. f. et Th.) Warb. | 1 | 1 |
| 140. | MYRIST | Knema intermedia (Bl.) Warb. | 1 | 1 |
| 141. | MYRIST | Myristica cinnamomea King | 2 | 2 |
| 142. | MYRSIN | Ardisia tuberculata Wall. | 2 | 1 |
| 143. | MYRSIN | Ardisia teysmanniana Scheff. | 1 | 1 |

*(Appendix 1:a cont.)*

| Rec.# | Family | Species | Total | DI |
|---|---|---|---|---|
| 144. | MYRSIN | Maesa ramentacea Wall. | 1 | 1 |
| 145. | MYRTA | Eugenia chlorantha Duthie | 1 | 1 |
| 146. | MYRTA | Eugenia filiformis Duthie | 3 | 2 |
| 147. | MYRTA | Eugenia glauca King | 1 | 1 |
| 148. | MYRTA | Eugenia linocieroidea King | 5 | 2 |
| 149. | MYRTA | Eugenia ngadimaniana Hend. | 2 | 2 |
| 150. | MYRTA | Eugenia palembanica (Miq.) Merr. | 2 | 1 |
| 151. | MYRTA | Eugenia rugosa (Korth) Merr. | 5 | 5 |
| 152. | MYRTA | Eugenia subdecussata Duthie | 4 | 2 |
| 153. | MYRTA | Eugenia sp. A | 2 | 2 |
| 154. | MYRTA | Eugenia sp. B | 2 | 2 |
| 155. | MYRTA | Eugenia sp. C | 2 | 1 |
| 156. | MYRTA | Rhodamnia cinerea Jack<br>(Rhodamnia trinervia Bl.) | 16 | 3 |
| 157. | MYRTA | Tristania merguensis Griff. | 1 | 1 |
| 158. | OCHNA | Gomphia serrata (Gaertn.) Kanis | 2 | 1 |
| 159. | OLACA | Ochanostachys amentacea Mast. | 5 | 5 |
| 160. | OLACA | Scorodocarpus borneensis Becc. | 5 | 4 |
| 161. | OLACA | Strombosia ceylanica Gardn.<br>(Strombosia rotundifolia King) | 1 | 1 |
| 162. | POLYGA | Xanthophyllum ellipticum Korth. ex Miq.<br>(Xanthophyllum kingii Chodat) | 1 | 1 |
| 163. | POLYGA | Xanthophyllum stipitatum Benn. | 4 | 4 |
| 164. | POLYGA | Xanthophyllum sp. | 1 | 1 |
| 165. | RHAMNA | Ziziphus calophylla Wall. | 1 | 1 |
| 166. | RHIZO | Gynotroches axillaris Bl. | 6 | 5 |
| 167. | RHIZO | Pellacalyx axillaris Korth. | 1 | 1 |
| 168. | RHIZO | Pellacalyx saccardianus Scort. | 28 | 10 |
| 169. | ROSA | Licania splendens (Korth.) Prance | 1 | 1 |
| 170. | ROSA | Prunus polystachya (Hk. f.) Kalkman | 1 | 1 |
| 171. | RUBIA | Pertusadina eurhyncha (Miq.) Ridsdale<br>(Adina rubescens Hemsl.) | 1 | 1 |
| 172. | RUBIA | Diplospora malaccensis Hk. f. | 1 | 1 |
| 173. | RUBIA | Nauclea officinalis (Pierre ex Pitard) Merr. et Chun.<br>(Nauclea junghuhnii Merr.) | 2 | 2 |
| 174. | RUBIA | Randia densiflora Benth. | 6 | 1 |
| 175. | RUBIA | Randia scortechinii King & Gamb. | 13 | 6 |
| 176. | RUBIA | Timonius wallichianus (Korth.) Valeton | 13 | 7 |
| 177. | RUBIA | Urophyllum glabrum Wall. ex Roxb. | 1 | 1 |
| 178. | RUTA | Euodia glabra (Bl.) Bl.<br>(Evodia glabra Bl.) | 5 | 2 |
| 179. | SABIA | Meliosma pinnata (Roxb.) Walp | 2 | 2 |
| 180. | SAPIND | Nephelium glabrum Noronoh | 2 | 1 |
| 181. | SAPIND | Nephelium lappaceum L. | 2 | 2 |
| 182. | SAPIND | Euphoria malaiensis (Griff.) Radlk.<br>(Nephelium malaiense Griff.) | 1 | 1 |
| 183. | SAPIND | Nephelium rubescens Hiern | 1 | 1 |
| 184. | SAPIND | Nephelium sp. | 1 | 1 |
| 185. | SAPIND | Pometia pinnata Forst. f. alnifolia (Bl.) Jacobs. | 2 | 1 |
| 186. | SAPIND | Xerospermum intermedium Radlk. | 1 | 1 |
| 187. | SAPOTA | Ganua kingiana (Brace) van den Assem | 4 | 3 |
| 188. | SAPOTA | Palaquium gutta (Hk.f.) Baillon | 38 | 4 |

*(Appendix 1:a cont.)*

| Rec.# | Family | Species | Total | DI |
|---|---|---|---|---|
| 189. | SAPOTA | Palaquium hexandrum (Griff.) Baillon | 4 | 1 |
| 190. | SAPOTA | Palaquium microphyllum King & Gamb. | 2 | 2 |
| 191. | SAPOTA | Palaquium obovatum (Griff.) Engl. | 2 | 2 |
| 192. | SAPOTA | Palaquium semaram H.J. Lam | 6 | 6 |
| 193. | SAPOTA | Payena obscura Burck | 1 | 1 |
| 194. | SAPOTA | Planchonella maingayi (Clarke) van Royen | 1 | 1 |
| 195. | SIMARU | Eurycoma longifolia Jack | 1 | 1 |
| 196. | STERCU | Heritiera elata Ridl. | 2 | 2 |
| 197. | STERCU | Scaphium macropodum (Miq.) Beumee ex Heyne (Scaphium affine Miq.) | 1 | 1 |
| 198. | STERCU | Heritiera simplicifolia (Mast.) Kosterm. (Tarrietia simplicifolia Mast.) | 1 | 1 |
| 199. | THEA | Adinandra acuminata Korth. | 1 | 1 |
| 200. | THEA | Adinandra dumosa Jack | 90 | 4 |
| 201. | THEA | Ploiarium alternifolium (Vahl) Melchior | 1 | 1 |
| 202. | THEA | Ternstroemia bancana Miq. | 1 | 1 |
| 203. | THEA | Gordonia multinervis King | 1 | 1 |
| 204. | THEA | Gordonia singaporeana Wall. ex Ridl. | 1 | 1 |
| 205. | THYMEL | Aquilaria malaccensis Lamk. | 1 | 1 |
| 206. | TILIA | Grewia blattaefolia Corner | 5 | 3 |
| 207. | TILIA | Pentace triptera Mast. | 3 | 2 |
| 208. | MORA | Ficus dubia Wall. ex King | 1 | 1 |
| 209. | ULMA | Gironniera nervosa Planch. | 4 | 3 |
| 210. | ULMA | Gironniera parvifolia Planch. | 8 | 5 |
| 211. | ULMA | Streblus elongatus (Miq.) Corner (Sloetia elongata (Miq.) Koord.) | 19 | 7 |
| 212. | VERBEN | Teijsmanniodendron coriaceum (Clarke) Kosterm. | 2 | 1 |
| 213. | | Unknown | 20 | 13 |

## Appendix 1: b. Families arranged according to descending order of species preponderence.
(All species with gbh > = 12 inches)

| | Family | No. of Genera | No. of Species | Sample Total |
|---|---|---|---|---|
| 1. | Euphorbiaceae | 11 | 22 | 70 |
| 2. | Burseraceae | 3 | 13 | 41 |
| 3. | Dipterocarpaceae | 5 | 13 | 125 |
| 4. | Myrtaceae | 3 | 13 | 46 |
| 5. | Lauraceae | 6 | 13 | 26 |
| 6. | Leguminosae | 3 | 11 | 28 |
| 7. | Anonaceae | 5 | 10 | 20 |
| 8. | Guttiferae | 2 | 8 | 19 |
| 9. | Sapotaceae | 4 | 8 | 58 |
| 10. | Sapindaceae | 4 | 7 | 10 |
| 11. | Myristicaceae | 4 | 7 | 9 |
| 12. | Rubiaceae | 6 | 7 | 37 |
| 13. | Fagaceae | 2 | 6 | 10 |
| 14. | Moraceae | 3 | 6 | 49 |
| 15. | Anacardiaceae | 5 | 6 | 58 |
| 16. | Theaceae | 3 | 5 | 94 |
| 17. | Meliaceae | 4 | 5 | 11 |
| 18. | Elaeocarpaceae | 1 | 4 | 6 |
| 19. | Ebenaceae | 1 | 4 | 5 |
| 20. | Melastomaceae | 2 | 3 | 10 |
| 21. | Sterculiaceae | 2 | 3 | 4 |
| 22. | Myrisinaceae | 2 | 3 | 4 |
| 23. | Rhizophoraceae | 2 | 3 | 35 |
| 24. | Olacaeae | 3 | 3 | 11 |
| 25. | Polygalaceae | 1 | 3 | 6 |
| 26. | Ixonanthaceae | 1 | 2 | 24 |
| 27. | Ulmaceae | 1 | 2 | 12 |
| 28. | Connaraceae | 2 | 2 | 2 |
| 29. | Rosaceae | 2 | 2 | 2 |
| 30. | Apocynaceae | 2 | 2 | 2 |
| 31. | Tiliaceae | 2 | 2 | 7 |
| 32. | Celastraceae | 2 | 2 | 5 |
| 33. | Rutaceae | 1 | 1 | 5 |
| 34. | Hypericaceae | 1 | 1 | 3 |
| 35. | Sabiaceae | 1 | 1 | 2 |
| 36. | Verbenaceae | 1 | 1 | 2 |
| 37. | Ochnaceae | 1 | 1 | 2 |
| 38. | Dilleniaceae | 1 | 1 | 2 |
| 39. | Magnoliaceae | 1 | 1 | 2 |
| 40. | Bombacaceae | 1 | 1 | 1 |
| 41. | Rhamnaceae | 1 | 1 | 1 |
| 42. | Simarubaceae | 1 | 1 | 1 |
| 43. | Ternstroemiaceae | 1 | 1 | 1 |
| 44. | Thymeliaceae | 1 | 1 | 1 |
| 45. | Unknown | 0 | 0 | 10 |
| | Total: | 111 | 212 | 889 |

## Appendix 2. Girth class distribution and spatial distribution of species as indicated by the Distribution Index (DI).

All species with girth>=12".
G1 & G2 obtained from only 1 of 4 sub-plots of each cluster.
For explanation on DI and girth size (G) equivalents see Sect. III (c) & III (d).
"TOT" is the Sample Total of the Species

| | Species | Code | G1 | G2 | G3 | G4 | G5 | G6 | TOT | DI |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. | Actinodaphne malaccensis | ACMA | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| 2. | Actinodaphne sesquipedalis | ACSE | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 |
| 3. | Adinandra acuminata | ADIN | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 |
| 4. | Agelaea trinervia | AGET | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 |
| 5. | Alstonia angustifolia | ALAN | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| 6. | Anaxagorea javanica | ANAX | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 |
| 7. | Anisoptera costata | ANIS | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 |
| 8. | Antidesma cuspidatum | ANTC | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 |
| 9. | Aporusa bracteosa | APBR | 1 | 2 | 2 | 0 | 0 | 0 | 5 | 1 |
| 10. | Aporusa prainiana | APPR | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 |
| 11. | Aporusa sp. A | APZA | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 12. | Aporusa sp. B | APZB | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 |
| 13. | Aquilaria malaccensis | AQMA | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| 14. | Ardisia teysmanniana | ARDT | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 |
| 15. | Ardisia tuberculata | ARDI | 0 | 1 | 1 | 0 | 0 | 0 | 2 | 1 |
| 16. | Artocarpus kemando | ARKE | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 |
| 17. | Baccaurea sp. B | BAZB | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 18. | Bouea macrophylla | BOMA | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 |
| 19. | Bouea oppositifolia | BOOP | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 |
| 20. | Calophyllum rubiginosum | CALR | 0 | 2 | 0 | 0 | 0 | 0 | 2 | 1 |
| 21. | Calophyllum wallichianum | CALW | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 |
| 22. | Canarium grandifolium | CANA | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 |
| 23. | Canarium sp | CANP | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| 24. | Castanopsis megacarpa | CASM | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 |
| 25. | Castanopsis wallichii | CAST | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 |
| 26. | Castanopsis sp. | CAZP | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 |
| 27. | Chisocheton erythrocarpus | CHER | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| 28. | Cinnamomum zeylanicum | CIZE | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 |
| 29. | Cryptocarya ferrea | CRFE | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 |
| 30. | Cryptocarya rugulosa | CRRU | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| 31. | Cyathocalyx ridleyi | CYRI | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 |
| 32. | Dacryodes costata | DACO | 0 | 0 | 1 | 1 | 0 | 0 | 2 | 1 |
| 33. | Dacryodes rugosa | DARU | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| 34. | Dialium maingayi | DIMA | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 |
| 35. | Dialium patens | DIPA | 0 | 0 | 1 | 0 | 1 | 0 | 2 | 1 |
| 36. | Dialium platysepalum | DIPL | 0 | 1 | 1 | 0 | 0 | 1 | 3 | 1 |
| 37. | Dialium wallichii | DIWA | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 1 |
| 38. | Diospyros lanceifolia | DOLA | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 |
| 39. | Diospyros maingayi | DOMA | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 |
| 40. | Diospyros sp. | DOSP | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| 41. | Diplospora malaccensis | DPMA | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 |
| 42. | Dipterocarpus sublamellatus | DPRS | 0 | 0 | 3 | 0 | 0 | 0 | 3 | 1 |
| 43. | Durio griffithii | DUGR | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| 44. | Dyera costulata | DYCO | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| 45. | Dysoxylon sp. | DYSP | 0 | 4 | 1 | 0 | 0 | 0 | 5 | 1 |
| 46. | Elaeocarpus nitidus | ELAN | 0 | 0 | 0 | 2 | 0 | 0 | 2 | 1 |
| 47. | Elaeocarpus petiolatus | ELAP | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 |
| 48. | Elaeocarpus polystachyus | ELAS | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |

*(Appendix 2 contd.)*

| | Species | Code | G1 | G2 | G3 | G4 | G5 | G6 | TOT | DI |
|---|---|---|---|---|---|---|---|---|---|---|
| 49. | Ellipanthus tomentosus | ELTO | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 |
| 50. | Eugenia chlorantha | EUCH | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| 51. | Eugenia glauca | EUGL | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| 52. | Eugenia palembanica | EUPA | 0 | 2 | 0 | 0 | 0 | 0 | 2 | 1 |
| 53. | Eugenia sp. C | EUZD | 0 | 0 | 2 | 0 | 0 | 0 | 2 | 1 |
| 54. | Euphoria malaiensis | NEMA | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 55. | Eurycoma longifolia | EVLO | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 |
| 56. | Ficus dubia | FICD | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| 57. | Fissistigma lanuginosum | FILA | 0 | 0 | 1 | 1 | 0 | 0 | 2 | 1 |
| 58. | Fissistigma latifolium | FILT | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 |
| 59. | Garcinia rostrata | GARR | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 |
| 60. | Gomphia serrata | GOMS | 0 | 0 | 2 | 0 | 0 | 0 | 2 | 1 |
| 61. | Gordonia multinervis | GOMU | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| 62. | Gordonia singaporeana | GOSI | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 |
| 63. | Gymnacranthera forbesii | GYFO | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 |
| 64. | Horsfieldia brachiata | HORB | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| 65. | Horsfieldia superba | HOSU | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 |
| 66. | Knema hookeriana | KNHO | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 |
| 67. | Knema intermedia | KNIN | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| 68. | Koilodepas longifolium | KOLO | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| 69. | Kokoona reflexa | LORE | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 |
| 70. | Licania splendens | LICA | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 |
| 71. | Lithocarpus ewyckii | LIEW | 0 | 0 | 1 | 1 | 0 | 0 | 2 | 1 |
| 72. | Litsea costalis | LITC | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 |
| 73. | Litsea gracilipes | LITG | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 |
| 74. | Litsea grandis | LITN | 0 | 0 | 0 | 1 | 1 | 0 | 2 | 1 |
| 75. | Macaranga conifera | MACO | 0 | 0 | 0 | 0 | 2 | 0 | 2 | 1 |
| 76. | Macaranga lowii | MALO | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| 77. | Mallotus penangensis | MAPE | 1 | 3 | 0 | 0 | 1 | 0 | 5 | 1 |
| 78. | Maesa ramentacea | MARA | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| 79. | Memecylon coeruleum | MECO | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 |
| 80. | Meliosma pinnata | MEPI | 0 | 1 | 1 | 0 | 0 | 0 | 2 | 1 |
| 81. | Nephelium glabrum | NEGL | 0 | 0 | 1 | 1 | 0 | 0 | 2 | 1 |
| 82. | Nephelium rubescens | NERU | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 |
| 83. | Nephelium sp. | NESP | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 |
| 84. | Nothaphoebe umbelliflora | NOUM | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| 85. | Palaquium hexandrum | PAHE | 0 | 0 | 0 | 2 | 1 | 1 | 4 | 1 |
| 86. | Payena obscura | PAYA | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| 87. | Pellacalyx axillaris | PEAX | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| 88. | Pertusadina eurhyncha | ADIA | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| 89. | Ploiarium alternifolium | PLAL | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 |
| 90. | Planchonella maingayi | PLMA | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| 91. | Polyalthia hookeriana | POHO | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 |
| 92. | Polyalthia rumphii | POLR | 0 | 0 | 1 | 1 | 0 | 0 | 2 | 1 |
| 93. | Polyalthia sp. | POLS | 0 | 2 | 0 | 0 | 0 | 0 | 2 | 1 |
| 94. | Pometia pinnata f. alnifolia | POMA | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 1 |
| 95. | Prunus polystachya | PRPO | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| 96. | Randia densiflora | RADE | 1 | 3 | 2 | 0 | 0 | 0 | 6 | 1 |
| 97. | Sandoricum koetjapi | SAND | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 |
| 98. | Santiria apiculata | SANE | 1 | 1 | 0 | 0 | 0 | 0 | 2 | 1 |
| 99. | Santiria sp. A | SAZA | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 |
| 100. | Santiria sp. B | SAZB | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 |
| 101. | Scaphium macropodum | SCAF | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 |
| 102. | Shorea bracteolata | SHBR | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| 103. | Sindora coriacea | SICO | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 |
| 104. | Sindora echinocalyx | SIEC | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 |

*(Appendix 2 contd.)*

| | Species | Code | G1 | G2 | G3 | G4 | G5 | G6 | TOT | DI |
|---|---|---|---|---|---|---|---|---|---|---|
| 105. | Sindora velutina | SIVE | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 |
| 106. | Sindora sp. | SIZP | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| 107. | Strombosia ceylanica | STRO | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 |
| 108. | Heritiera simplicifolia | TASI | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| 109. | Ternstroemia bancana | TEBA | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 |
| 110. | Teijsmanniodendron coriaceum | TJCO | 0 | 2 | 0 | 0 | 0 | 0 | 2 | 1 |
| 111. | Tristania merguensis | TRME | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| 112. | Urophyllum glabrum | URGL | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| 113. | Vatica maingayi | VASA | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 |
| 114. | Vatica sp. A | VASB | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| 115. | Xanthophyllum ellipticum | XAKI | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 |
| 116. | Xanthophyllum sp. | XAZP | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 |
| 117. | Xerospermum intermedium | XEIN | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 |
| 118. | Xylopia ferruginea | XYFE | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 |
| 119. | Ziziphus calophylla | ZICA | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 |
| 120. | Aglaia trichostemon | AGLT | 0 | 0 | 0 | 1 | 1 | 0 | 2 | 2 |
| 121. | Aglaia sp. | AGSP | 0 | 0 | 2 | 0 | 0 | 0 | 2 | 2 |
| 122. | Aporusa benthamiana | APBE | 0 | 0 | 1 | 1 | 0 | 0 | 2 | 2 |
| 123. | Aromadendron elegans | AREL | 1 | 0 | 0 | 0 | 0 | 1 | 2 | 2 |
| 124. | Baccaurea bracteata | BABR | 1 | 0 | 1 | 0 | 0 | 0 | 2 | 2 |
| 125. | Baccaurea maingayi | BAMA | 0 | 0 | 2 | 0 | 0 | 0 | 2 | 2 |
| 126. | Baccaurea sp. A | BAZA | 0 | 0 | 1 | 0 | 1 | 0 | 2 | 2 |
| 127. | Bhesa paniculata | BHPA | 0 | 2 | 2 | 0 | 0 | 0 | 4 | 2 |
| 128. | Buchanania sessilifolia | BUSE | 2 | 0 | 0 | 0 | 0 | 0 | 2 | 2 |
| 129. | Calophyllum curtisii | CALC | 0 | 0 | 0 | 0 | 1 | 2 | 3 | 2 |
| 130. | Dacryodes laxa var typica | DALA | 0 | 1 | 0 | 0 | 0 | 1 | 2 | 2 |
| 131. | Dacryodes rostrata | DARO | 1 | 0 | 0 | 0 | 0 | 1 | 2 | 2 |
| 132. | Dialium laurinum | DILA | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 2 |
| 133. | Dillenia grandifolia | DLEX | 0 | 1 | 0 | 1 | 0 | 0 | 2 | 2 |
| 134. | Diospyros buxifolia | DOBU | 0 | 1 | 1 | 0 | 0 | 0 | 2 | 2 |
| 135. | Elaeocarpus acronodia | ELAM | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 2 |
| 136. | Elateriospermum tapos | ELTA | 0 | 0 | 1 | 0 | 0 | 1 | 2 | 2 |
| 137. | Eugenia filiformis | EUFI | 0 | 2 | 1 | 0 | 0 | 0 | 3 | 2 |
| 138. | Eugenia linocieroidea | EULI | 0 | 0 | 5 | 0 | 0 | 0 | 5 | 2 |
| 139. | Eugenia ngadimaniana | EUNG | 0 | 1 | 1 | 0 | 0 | 0 | 2 | 2 |
| 140. | Eugenia subdecussata | EUSU | 0 | 0 | 4 | 0 | 0 | 0 | 4 | 2 |
| 141. | Eugenia sp. A | EUZA | 0 | 0 | 2 | 0 | 0 | 0 | 2 | 2 |
| 142. | Eugenia sp. B | EUZB | 0 | 0 | 2 | 0 | 0 | 0 | 2 | 2 |
| 143. | Euodia glabra | EVOD | 0 | 1 | 1 | 2 | 1 | 0 | 5 | 2 |
| 144. | Garcinia hombroniana | GARH | 0 | 1 | 1 | 0 | 0 | 0 | 2 | 2 |
| 145. | Garcinia nigrolineata | GARN | 0 | 1 | 1 | 0 | 0 | 0 | 2 | 2 |
| 146. | Gymnacranthera eugeniifolia | GYEU | 0 | 1 | 0 | 1 | 0 | 0 | 2 | 2 |
| 147. | Heritiera elata | HEEL | 0 | 1 | 0 | 1 | 0 | 0 | 2 | 2 |
| 148. | Lithocarpus conocarpus | LICO | 0 | 0 | 1 | 1 | 0 | 0 | 2 | 2 |
| 149. | Litsea machilifolia | LITS | 0 | 0 | 2 | 0 | 0 | 0 | 2 | 2 |
| 150. | Myristica cinnamomea | MYCI | 0 | 1 | 0 | 1 | 0 | 0 | 2 | 2 |
| 151. | Nauclea officinalis | NAJU | 0 | 0 | 2 | 0 | 0 | 0 | 2 | 2 |
| 152. | Nephelium lappaceum | NELA | 0 | 0 | 1 | 0 | 0 | 1 | 2 | 2 |
| 153. | Palaquium microphyllum | PALM | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 2 |
| 154. | Palaquium obovatum | PALO | 0 | 1 | 1 | 0 | 0 | 0 | 2 | 2 |
| 155. | Pentace triptera | PETR | 0 | 0 | 2 | 0 | 0 | 1 | 3 | 2 |
| 156. | Pternandra coerulescens | PTCO | 0 | 0 | 1 | 1 | 0 | 0 | 2 | 2 |
| 157. | Ptychopyxis caput-medusae | PTYC | 1 | 0 | 1 | 0 | 2 | 1 | 4 | 2 |
| 158. | Santiria tomentosa | SANT | 1 | 0 | 1 | 1 | 0 | 0 | 3 | 2 |
| 159. | Shorea gratissima | SHGR | 0 | 0 | 0 | 1 | 0 | 2 | 3 | 2 |
| 160. | Xylopia malayana | XYMA | 0 | 2 | 0 | 0 | 0 | 0 | 2 | 2 |

*(Appendix 2 contd.)*

| | Species | Code | G1 | G2 | G3 | G4 | G5 | G6 | TOT | DI |
|---|---|---|---|---|---|---|---|---|---|---|
| 161. | Antidesma coriaceum | ANOM | 0 | 0 | 2 | 1 | 0 | 0 | 3 | 3 |
| 162. | Beilschmiedia maingayi | BEMA | 0 | 0 | 3 | 0 | 0 | 0 | 3 | 3 |
| 163. | Calophyllum pulcherrimum | CALP | 0 | 1 | 0 | 2 | 0 | 1 | 4 | 3 |
| 164. | Campnosperma auriculatum | CAMA | 0 | 1 | 6 | 3 | 2 | 4 | 16 | 3 |
| 165. | Cratoxylon formosum | CRFO | 0 | 0 | 1 | 1 | 0 | 1 | 3 | 3 |
| 166. | Dialium kingii | DIKI | 0 | 1 | 2 | 0 | 1 | 0 | 4 | 3 |
| 167. | Dipterocarpus kerii | DPRI | 0 | 0 | 2 | 1 | 0 | 2 | 5 | 3 |
| 168. | Ganua kingiana | GANK | 0 | 1 | 2 | 1 | 0 | 0 | 4 | 3 |
| 169. | Gironniera nervosa | GINE | 0 | 3 | 1 | 0 | 0 | 0 | 4 | 3 |
| 170. | Grewia blattaefolia | GRBL | 0 | 1 | 4 | 0 | 0 | 0 | 4 | 3 |
| 171. | Lithocarpus encleisacarpus | LIEN | 0 | 0 | 1 | 1 | 1 | 0 | 3 | 3 |
| 172. | Litsea elliptica | LITE | 0 | 0 | 2 | 1 | 0 | 0 | 3 | 3 |
| 173. | Rhodamnia cinerea | RHTR | 1 | 6 | 8 | 1 | 0 | 0 | 16 | 3 |
| 174. | Shorea macroptera | SHMA | 0 | 0 | 0 | 2 | 1 | 1 | 4 | 3 |
| 175. | Adinandra dumosa | ADIU | 0 | 27 | 52 | 9 | 2 | 0 | 90 | 4 |
| 176. | Artocarpus scortechinii | ARSC | 0 | 0 | 1 | 2 | 1 | 1 | 5 | 4 |
| 177. | Blumeodendron tokbrai | BLTO | 0 | 1 | 2 | 1 | 1 | 0 | 5 | 4 |
| 178. | Calophyllum ferrugineum | CALF | 0 | 0 | 2 | 1 | 1 | 0 | 4 | 4 |
| 179. | Endospermum diadenum | ENDO | 0 | 1 | 2 | 1 | 0 | 0 | 4 | 4 |
| 180. | Hopea mengarawan | HOME | 0 | 1 | 0 | 3 | 0 | 0 | 4 | 4 |
| 181. | Ixonanthes icosandra | IXIC | 0 | 2 | 2 | 0 | 0 | 0 | 4 | 4 |
| 182. | Palaquium gutta | PAGU | 0 | 2 | 10 | 13 | 7 | 6 | 38 | 4 |
| 183. | Parishia paucijuga | PARP | 0 | 0 | 2 | 0 | 1 | 1 | 4 | 4 |
| 184. | Santiria rubiginosa | SANR | 0 | 0 | 3 | 0 | 0 | 2 | 5 | 4 |
| 185. | Scorodocarpus borneensis | SCBO | 0 | 0 | 3 | 1 | 1 | 0 | 5 | 4 |
| 186. | Xanthophyllum stipitatum | XAST | 0 | 0 | 3 | 1 | 0 | 0 | 4 | 4 |
| 187. | Baccaurea kunstleri | BAKU | 0 | 1 | 3 | 0 | 1 | 4 | 9 | 5 |
| 188. | Baccaurea sumatrana | BASU | 0 | 2 | 2 | 2 | 0 | 0 | 6 | 5 |
| 189. | Eugenia rugosa | EURA | 0 | 2 | 1 | 0 | 1 | 1 | 5 | 5 |
| 190. | Gironniera parvifolia | GIPA | 1 | 3 | 3 | 1 | 0 | 0 | 8 | 5 |
| 191. | Gynotroches axillaris | GYNO | 0 | 2 | 2 | 2 | 0 | 0 | 6 | 5 |
| 192. | Litsea castanea | LITA | 0 | 0 | 4 | 4 | 0 | 0 | 8 | 5 |
| 193. | Ochanostachys amentacea | OCAM | 0 | 2 | 0 | 2 | 0 | 1 | 5 | 5 |
| 194. | Pternandra echinata | PTEC | 0 | 1 | 1 | 4 | 0 | 1 | 7 | 5 |
| 195. | Shorea leprosula | SHLE | 0 | 2 | 0 | 1 | 3 | 4 | 10 | 5 |
| 196. | Artocarpus rigidus | ARRI | 0 | 1 | 2 | 3 | 1 | 2 | 9 | 6 |
| 197. | Cyathocalyx ramuliflorus | CYRA | 0 | 1 | 6 | 0 | 0 | 0 | 7 | 6 |
| 198. | Ixonanthes reticulata | IXRE | 0 | 0 | 4 | 2 | 4 | 10 | 20 | 6 |
| 199. | Koompassia malaccensis | KOMA | 0 | 3 | 1 | 1 | 0 | 5 | 10 | 6 |
| 200. | Palaquium semaram | PALS | 0 | 0 | 1 | 1 | 3 | 1 | 6 | 6 |
| 201. | Randia scortechinii | RASC | 0 | 7 | 4 | 2 | 0 | 0 | 13 | 6 |
| 202. | Shorea pauciflora | SHPA | 0 | 0 | 3 | 0 | 1 | 5 | 9 | 6 |
| 203. | Pimelodendron griffithianum | PIGR | 0 | 1 | 5 | 2 | 0 | 1 | 9 | 7 |
| 204. | Streblus elongatus | SLOE | 1 | 3 | 5 | 6 | 2 | 2 | 19 | 7 |
| 205. | Timonius wallichianus | TIWA | 1 | 6 | 5 | 1 | 0 | 0 | 13 | 7 |
| 206. | Santiria griffithii | SANG | 1 | 4 | 0 | 3 | 2 | 2 | 12 | 8 |
| 207. | Santiria laevigata | SANL | 0 | 0 | 2 | 5 | 0 | 1 | 8 | 8 |
| 208. | Pellacalyx saccardianus | PESA | 0 | 6 | 9 | 6 | 5 | 2 | 28 | 10 |
| 209. | Artocarpus lanceifolius | ARLA | 0 | 3 | 4 | 4 | 2 | 1 | 15 | 11 |
| 210. | Dipterocarpus caudatus ssp. penangianus | DPRP | 0 | 8 | 7 | 5 | 2 | 15 | 37 | 12 |
| 211. | Shorea curtisii | SHCU | 0 | 5 | 10 | 5 | 7 | 19 | 46 | 12 |
| 212. | Unknown | ZNKN | 1 | 6 | 8 | 1 | 0 | 4 | 20 | 13 |
| 213. | Gluta wallichii | MELW | 0 | 5 | 15 | 10 | 2 | 2 | 34 | 15 |

## Appendix 3. Species with individuals in specified ranges of girth classes.

"TOT" is the Species' Sample Total.
For DI and G see Sect. III (c) & III (d)

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**a Species with individuals in the whole range of girth classes.**

| | Species | Code | G1 | G2 | G3 | G4 | G5 | G6 | TOT | DI |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. | Streblus elongatus | SLOE | 1 | 3 | 5 | 6 | 2 | 2 | 19 | 7 |

**b Species which must have individuals from G2 thr'u to G6.**

| | Species | Code | G1 | G2 | G3 | G4 | G5 | G6 | TOT | DI |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. | Artocarpus lanceifolius | ARLA | 0 | 3 | 4 | 4 | 2 | 1 | 14 | 11 |
| 2. | Artocarpus rigidus | ARRI | 0 | 1 | 2 | 3 | 1 | 2 | 9 | 6 |
| 3. | Campnosperma auriculatum | CAMA | 0 | 1 | 6 | 3 | 2 | 4 | 16 | 3 |
| 4. | Dipterocarpus caudatus ssp. penangianus | DRRP | 0 | 8 | 7 | 5 | 2 | 15 | 37 | 12 |
| 5. | Gluta wallichii | MELW | 0 | 5 | 15 | 10 | 2 | 2 | 34 | 15 |
| 6. | Palaquium gutta | PAGU | 0 | 2 | 10 | 13 | 7 | 6 | 38 | 4 |
| 7. | Pellacalyx saccardianus | PESA | 0 | 6 | 9 | 6 | 5 | 2 | 28 | 10 |
| 8. | Shorea curtisii | SHCU | 0 | 5 | 10 | 5 | 7 | 19 | 46 | 12 |
| 9. | Streblus elongatus | SLOE | 1 | 3 | 5 | 6 | 2 | 2 | 19 | 7 |

**c Species which must have individuals from G3 thr'u to G6.**

| | Species | Code | G1 | G2 | G3 | G4 | G5 | G6 | TOT | DI |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. | Atrocarpus lanceifolius | ARLA | 0 | 3 | 4 | 4 | 2 | 1 | 14 | 11 |
| 2. | Artocarpus rigidus | ARRI | 0 | 1 | 2 | 3 | 1 | 2 | 9 | 6 |
| 3. | Artocarpus scortechinii | ARSC | 0 | 0 | 1 | 2 | 1 | 1 | 5 | 4 |
| 4. | Campnosperma auriculatum | CAMA | 0 | 1 | 6 | 3 | 2 | 4 | 16 | 3 |
| 5. | Dipterocarpus caudatus ssp. penangianus | DPRP | 0 | 8 | 7 | 5 | 2 | 15 | 37 | 12 |
| 6. | Ixonanthes reticulata | IXRE | 0 | 0 | 4 | 2 | 4 | 10 | 20 | 6 |
| 7. | Gluta wallichii | MELW | 0 | 5 | 15 | 10 | 2 | 2 | 34 | 15 |
| 8. | Palaquium gutta | PAGU | 0 | 2 | 10 | 13 | 7 | 6 | 38 | 4 |
| 9. | Palaquium semaram | PALS | 0 | 0 | 1 | 1 | 3 | 1 | 6 | 6 |
| 10. | Pellacalyx saccardianus | PESA | 0 | 6 | 9 | 6 | 5 | 2 | 28 | 10 |
| 11. | Shorea curtisii | SHCU | 0 | 5 | 10 | 5 | 7 | 19 | 46 | 12 |
| 12. | Streblus elongatus | SLOE | 1 | 3 | 5 | 6 | 2 | 2 | 19 | 7 |

**d Species which must have individuals from G4 thr'u to G6.**

| | Species | Code | G1 | G2 | G3 | G4 | G5 | G6 | TOT | DI |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. | Artocarpus lanceifolius | ARLA | 0 | 3 | 4 | 4 | 2 | 1 | 14 | 11 |
| 2. | Artocarpus rigidus | ARRI | 0 | 1 | 2 | 3 | 1 | 2 | 9 | 6 |
| 3. | Artocarpus scortechinii | ARSC | 0 | 0 | 1 | 2 | 1 | 1 | 5 | 4 |
| 4. | Campnosperma auriculatum | CAMA | 0 | 1 | 6 | 3 | 2 | 4 | 16 | 3 |
| 5. | Dipterocarpus caudatus ssp. penangianus | DPRP | 0 | 8 | 7 | 5 | 2 | 15 | 37 | 12 |
| 6. | Ixonanthes reticulata | IXRE | 0 | 0 | 4 | 2 | 4 | 10 | 20 | 6 |
| 7. | Gluta wallichii | MELW | 0 | 5 | 15 | 10 | 2 | 2 | 34 | 15 |
| 8. | Palaquium gutta | PAGU | 0 | 2 | 10 | 13 | 7 | 6 | 38 | 4 |
| 9. | Palaquium hexandrum | PAHE | 0 | 0 | 0 | 2 | 1 | 1 | 4 | 1 |
| 10. | Palaquium semaram | PALS | 0 | 0 | 1 | 1 | 3 | 1 | 6 | 6 |
| 11. | Pellacalyx saccardianus | PESA | 0 | 6 | 9 | 6 | 5 | 2 | 28 | 10 |
| 12. | Santiria griffithii | SANG | 1 | 4 | 0 | 3 | 2 | 2 | 12 | 8 |
| 13. | Shorea curtisii | SHCU | 0 | 5 | 10 | 5 | 7 | 19 | 46 | 12 |
| 14. | Shorea leprosula | SHLE | 0 | 2 | 0 | 1 | 3 | 4 | 10 | 5 |
| 15. | Shorea macroptera | SHMA | 0 | 0 | 0 | 2 | 1 | 1 | 4 | 3 |
| 16. | Streblus elongatus | SLOE | 1 | 3 | 5 | 6 | 2 | 2 | 19 | 7 |

## Appendix 4. Number of species which have individuals in girth class G1 and/or girth class G2.

"TOT" is the Species' Sample Total.
For G and DI see Sect. III (c) & III (d) for explanation.

| | Species | G1 | G2 | G3 | G4 | G5 | G6 | TOT | DI |
|---|---|---|---|---|---|---|---|---|---|
| 1. | Actinodaphne malaccensis | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| 2. | Adinandra dumosa | 0 | 27 | 52 | 9 | 2 | 0 | 90 | 4 |
| 3. | Alstonia angustifolia | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| 4. | Aporusa bracteosa | 1 | 2 | 2 | 0 | 0 | 0 | 5 | 1 |
| 5. | Aporusa sp. A | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 6. | Ardisia tuberculata | 0 | 1 | 1 | 0 | 0 | 0 | 2 | 1 |
| 7. | Aromadendron elegans | 1 | 0 | 0 | 0 | 0 | 1 | 2 | 2 |
| 8. | Artocarpus lanceifolius | 0 | 3 | 4 | 4 | 2 | 1 | 14 | 11 |
| 9. | Artocarpus rigidus | 0 | 1 | 2 | 3 | 1 | 2 | 9 | 6 |
| 10. | Baccaurea bracteata | 1 | 0 | 1 | 0 | 0 | 0 | 2 | 2 |
| 11. | Baccaurea kunstleri | 0 | 1 | 3 | 0 | 1 | 4 | 9 | 5 |
| 12. | Baccaurea sumatrana | 0 | 2 | 2 | 2 | 0 | 0 | 6 | 5 |
| 13. | Baccaurea sp. B | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 14. | Bhesa paniculata | 0 | 2 | 2 | 0 | 0 | 0 | 4 | 2 |
| 15. | Blumeodendron tokbrai | 0 | 1 | 2 | 1 | 1 | 0 | 5 | 4 |
| 16. | Buchanania sessilifolia | 2 | 0 | 0 | 0 | 0 | 0 | 2 | 2 |
| 17. | Calohyllum pulcherrimum | 0 | 1 | 0 | 2 | 0 | 1 | 4 | 3 |
| 18. | Calophyllum rubiginosum | 0 | 2 | 0 | 0 | 0 | 0 | 2 | 1 |
| 19. | Campnosperma auriculatum | 0 | 1 | 6 | 3 | 2 | 4 | 16 | 3 |
| 20. | Canarium sp | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| 21. | Chisocheton erythrocarpus | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| 22. | Cryptocarya rugulosa | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| 23. | Cyathocalyx ramuliflorus | 0 | 1 | 6 | 0 | 0 | 0 | 7 | 6 |
| 24. | Dacryodes laxa var typica | 0 | 1 | 0 | 0 | 0 | 1 | 2 | 2 |
| 25. | Dacryodes rostrata | 1 | 0 | 0 | 0 | 0 | 1 | 2 | 2 |
| 26. | Dacryodes rugosa | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| 27. | Dialium kingii | 0 | 1 | 2 | 0 | 1 | 0 | 4 | 3 |
| 28. | Dialium platysepalum | 0 | 1 | 1 | 0 | 0 | 1 | 3 | 1 |
| 29. | Dillenia grandifolia | 0 | 1 | 0 | 1 | 0 | 0 | 2 | 2 |
| 30. | Diospyros buxifolia | 0 | 1 | 1 | 0 | 0 | 0 | 2 | 2 |
| 31. | Dipterocarpus caudatus ssp. penangianus | 0 | 8 | 7 | 5 | 2 | 15 | 37 | 12 |
| 32. | Durio griffithii | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| 33. | Dyera costulata | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| 34. | Dysoxylon sp. | 0 | 4 | 1 | 0 | 0 | 0 | 5 | 1 |
| 35. | Elaeocarpus polystachyus | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 36. | Endospermum diadenum | 0 | 1 | 2 | 1 | 0 | 0 | 4 | 4 |
| 37. | Eugenia chlorantha | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| 38. | Eugenia filiformis | 0 | 2 | 1 | 0 | 0 | 0 | 3 | 2 |
| 39. | Eugenia glauca | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| 40. | Eugenia ngadimaniana | 0 | 1 | 1 | 0 | 0 | 0 | 2 | 2 |
| 41. | Eugenia palembanica | 0 | 2 | 0 | 0 | 0 | 0 | 2 | 1 |
| 42. | Eugenia rugosa | 0 | 2 | 1 | 0 | 1 | 1 | 5 | 5 |
| 43. | Euodia glabra | 0 | 1 | 1 | 2 | 1 | 0 | 5 | 2 |
| 44. | Ganua kingiana | 0 | 1 | 2 | 1 | 0 | 0 | 4 | 3 |
| 45. | Garcinia hombroniana | 0 | 1 | 1 | 0 | 0 | 0 | 2 | 2 |
| 46. | Garcinia nigrolineata | 0 | 1 | 1 | 0 | 0 | 0 | 2 | 2 |
| 47. | Gironniera nervosa | 0 | 3 | 1 | 0 | 0 | 0 | 4 | 3 |
| 48. | Gironniera parvifolia | 1 | 3 | 3 | 1 | 0 | 0 | 8 | 5 |

*(Appendix 4 contd.)*

| | Species | Code | G1 | G2 | G3 | G4 | G5 | G6 | TOT | DI |
|---|---|---|---|---|---|---|---|---|---|---|
| 49. | Grewia blattaefolia | | 0 | 1 | 4 | 0 | 0 | 0 | 5 | 3 |
| 50. | Gymnacranthera eugeniifolia | | 0 | 1 | 0 | 1 | 0 | 0 | 2 | 2 |
| 51. | Gynotroches axillaris | | 0 | 2 | 2 | 2 | 0 | 0 | 6 | 5 |
| 52. | Heritiera elata | | 0 | 1 | 0 | 1 | 0 | 0 | 2 | 2 |
| 53. | Hopea mengarawan | | 0 | 1 | 0 | 3 | 0 | 0 | 4 | 4 |
| 54. | Horsfieldia brachiata | | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| 55. | Ixonanthes icosandra | | 0 | 2 | 2 | 0 | 0 | 0 | 4 | 4 |
| 56. | Knema intermedia | | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| 57. | Koilodepas longifolium | | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| 58. | Koompassia malaccensis | | 0 | 3 | 1 | 1 | 0 | 5 | 10 | 6 |
| 59. | Macaranga lowii | | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| 60. | Mallotus penangensis | | 1 | 3 | 0 | 0 | 1 | 0 | 5 | 1 |
| 61. | Maesa ramentacea | | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| 62. | Gluta wallichii | | 0 | 5 | 15 | 10 | 2 | 2 | 34 | 15 |
| 63. | Meliosma pinnata | | 0 | 1 | 1 | 0 | 0 | 0 | 2 | 2 |
| 64. | Myristica cinnamomea | | 0 | 1 | 0 | 1 | 0 | 0 | 2 | 2 |
| 65. | Euphoria malaiense | | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 66. | Nothaphoebe umbelliflora | | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| 67. | Ochanostachys amentacea | | 0 | 2 | 0 | 2 | 0 | 1 | 5 | 5 |
| 68. | Palaquium gutta | | 0 | 2 | 10 | 13 | 7 | 6 | 38 | 4 |
| 69. | Palaquium obovatum | | 0 | 1 | 1 | 0 | 0 | 0 | 2 | 2 |
| 70. | Pellacalyx saccardianus | | 0 | 6 | 9 | 6 | 5 | 2 | 28 | 10 |
| 71. | Pimelodendron griffithianum | | 0 | 1 | 5 | 2 | 0 | 1 | 9 | 7 |
| 72. | Polyalthia sp. | | 0 | 2 | 0 | 0 | 0 | 0 | 2 | 1 |
| 73. | Pternandra echinata | | 0 | 1 | 1 | 4 | 0 | 1 | 7 | 5 |
| 74. | Ptychopyxis caput-medusae | | 1 | 0 | 1 | 0 | 2 | 1 | 5 | 2 |
| 75. | Randia densiflora | | 1 | 3 | 2 | 0 | 0 | 0 | 6 | 1 |
| 76. | Randia scortechinii | | 0 | 7 | 4 | 2 | 0 | 0 | 13 | 6 |
| 77. | Rhodamnia cinerea | | 1 | 6 | 8 | 1 | 0 | 0 | 16 | 3 |
| 78. | Santiria apiculata | | 1 | 1 | 0 | 0 | 0 | 0 | 2 | 1 |
| 79. | Santiria griffithii | | 1 | 4 | 0 | 3 | 2 | 2 | 12 | 8 |
| 80. | Santiria tomentosa | | 1 | 0 | 0 | 1 | 0 | 0 | 2 | 1 |
| 81. | Shorea curtisii | | 0 | 5 | 10 | 5 | 7 | 19 | 46 | 12 |
| 82. | Shorea leprosula | | 0 | 2 | 0 | 1 | 3 | 4 | 10 | 5 |
| 83. | Streblus elongatus | | 1 | 3 | 5 | 6 | 2 | 2 | 19 | 7 |
| 84. | Timonius wallichianus | | 1 | 6 | 5 | 1 | 0 | 0 | 13 | 7 |
| 85. | Teijsmanniodendron coriaceum | | 0 | 2 | 0 | 0 | 0 | 0 | 2 | 1 |
| 86. | Urophyllum glabrum | | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| 87. | Vatica sp. A | | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| 88. | Xylopia malayana | | 0 | 2 | 0 | 0 | 0 | 0 | 2 | 2 |
| 89. | Unknown | | 1 | 6 | 8 | 1 | 0 | 4 | 20 | 13 |

The list above contains 87 known species and the "unknown" group with 20 trees. The individuals are distributed in the various girth classes as shown below:

| G1 | G2 | G3 | G4 | G5 | G6 | TOT |
|---|---|---|---|---|---|---|
| 21 | 181 | 202 | 102 | 45 | 82 | 633 |


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## SINGAPORE

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# A Preliminary Survey of the Fern Flora of Langkawi Islands

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## Abstract

A survey of the fern flora of Langkawi Islands is presented, including a summary of their habitats and ecology. Of the 145 infrageneric taxa recorded from the islands, 7 are introduced or naturalized and 6 are presumed rare or endemics. Species are listed for both indigenous and secondary plant communities.

## Introduction

Langkawi, the natural paradise in the northwestern coast of Peninsular Malaysia is noted for its sun, unspoilt white sandy beaches and clear blue water. This group of islands lie between 22 and 54 km off the coast of Perlis, the northern-most state of Peninsular Malaysia, and 112 km north of Penang. Compared to the mainland, these 99 islands are relatively free of any kind of pollution. Only the blasting of limestone in the Kubang Badak Quarry, may have caused considerable noise and dust pollution within its operational area. Traffic density is light and the only noticeable pollution is smoke from the burning padi straws and rice husks during harvesting season. The white sandy beaches of Pantai Cenang, Tanjung Rhu and Teluk Barau are only a few of the major tourist attractions of Langkawi. The beaches have been free of oil spillage from ships, rubbish or sewage. The islands are covered with gently rolling hills of lush tropical rainforest. They are sheltered from the effects of tropical storms by the chains of islands not very far from the shore lines of the main island. Langkawi is one of the great natural assets of Malaysia.

### Geography and Geology

Langkawi comprises six moderate sized islands and ninety-three other small islets (Fig. 1). These islands, formed of and flanked by towering masses of limestone as well as quartzite and granite are situated at 6°10′ to 6°27′ and 99°37′ to 99°56′ and lie about 48 km off the coast of mainland Kedah. Langkawi Island is by far the biggest and more important, with an area of about 939 square km. Next in size is Dayang Bunting Island, 24 km long, with Tuba Island on the east, separated by a strait so narrow that is appears like a river. West of Dayang Bunting is Singa Besar Island, Beras Basah Island and many islets. On the southwest of Langkawi Island is Rebak Besar and Tepur Islands; on the east Langgun and Tembus Islands, while on the southeast is Timun Island, separated from the main island by the deep and narrow Strait of Panchor. With the exception of Langkawi, Dayang Bunting and Tuba, the other islands are either uninhabited or support a handful of temporary occupants of fishermen.

The centre of Langkawi Island, composed of granite and dominated by Gunung Raya — the highest peak on the island, is almost entirely primary forest with few access routes into it. It is the only Virgin Jungle Reserve (VJR) with an area of 149 ha demarcated in Langkawi (Putz, 1978). The primary forest is undisturbed and representative of the forest here. The slopes are characteristically steep and severely drained. Large trees are found in scattered patches where milder slopes have allowed deeper soil to develop. North of Gunang Raya towards the coastal strip known as Pantai Pasir Hitam, is secondary forest, much of which has been cleared to make way for settlement and a cement factory in Kampung Ewa. Towards the northwest, there is a long serrated quartzite ridge with about fifteen peaks clad with virgin jungle which is appropriately called "Gunung Machinchang", the Chopped Mountain.

The middle-west and centre of Langkawi Island consist solely of granite. Again there is granite in Dayang Bunting, Tuba and Bumbun islands. Fine crystalline marble is found at the northeast end of Dayang Bunting, Rebak, Tepur, Beras Basah and Singa Besar islands and numerous islets in the vicinity are composed of quartzite and shale.

Limestone rock least affected by the granite is seen in certain islets such as Jong and Kora as well as in the bigger islands such as Langgun, Tanjung Dindang, Timun, Dayang Bunting and the northeast coast of Langkawi. The limestone is part of the carboniferous limestone formation that is also found in Sumatra, north of Peninsular Malaysia, Thailand, Indochina and Burma. The limestone hills rise from flat or undulating plains often with steep or over-hanging cliffs and some of them rise sheer from the water's edge where part of or even the entire coast is entirely limestone.

### Climate

The tropical islands of Langkawi share the same climatic patterns with northern Kedah in the Malay Peninsula. Day temperature is high and lies within a fairly narrow range of 35°–37° (Jones, 1978). Water temperature is around 26°–28°.

Rainfall recorded for ten years (1965–1975) from four districts average 260 cm annually (Jones, 1978). The islands experience a distinct and more severe dry season from November/December to March than is associated with the most part of Peninsular Malaysia. This corresponds to the northeast monsoon when the average monthly rainfall for January and February hardly exceeds 5 cm compared with an average for the year of about 260 cm. Two wet seasons occur during the change of monsoons, that is, during April and May when the monthly rainfall averages over 22.5 cm, and August to October when the average reaches over 27.5 cm per month. Between these two wet seasons occurs another dry period in June and July corresponding to the southwest monsoon when the rainfall averages between 17 and 20 cm.

## Observations

Langkawi has been the subject of many general biological investigations in the last hundred years or so (Maxwell, 1887; Ridley, 1908 and 1912; Henderson, 1939; Igo and Koike, 1966; Wilcocks, 1969; Yadab and Ratnasabapathy, 1974; Balgooy *et al.*, 1977; Chin, 1977; Kuthubutheen, 1981). However comprehensive accounts of any particular group of plants especially ferns, are still lacking. Sporadic collections have been made from time to time and among the notable fern collectors of the islands are M.R. Henderson, H.C. Robinson, C. Curtis, Md. Haniff, Md. Nur, H.N. Ridley, R.E. Holttum and recently Chin, R. Jaman and A. Bidin. Most of the specimens are kept at the herbaria in Singapore (SING), The Universiti Kebangsaan Malaysia Bangi (UKMB), University of Malaya (KLU) and Kew (K).

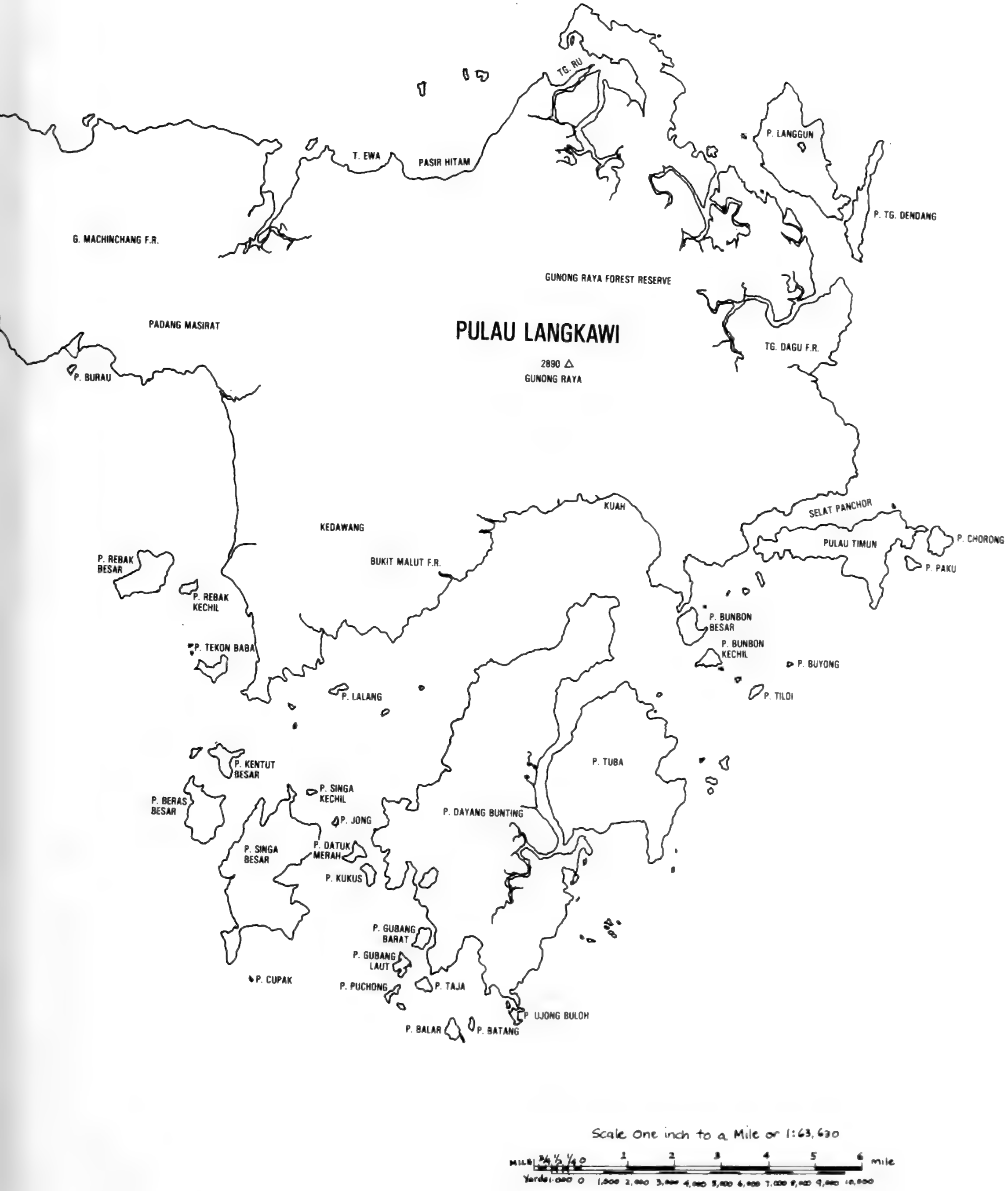

Fig. 1. Map of Langkawi Islands.

## Present Account

The present survey is based on the results of a number of field trips carried out in January, February, April and May 1986 by the author and a number of field assistants under a project sponsored by the Universiti Kebangsaan Malaysia in Bangi, as well as on observations of herbarium specimens deposited at the University of Malaya, The Universiti Kebangsaan Malaysia, Bangi and The Royal Botanic Gardens, Kew.

## Field Observations

A striking feature of the scenery in Langkawi is the occurrence of two main types of vegetation, limestone and granite. The vegetation of the limestone is primary forest, and only slightly disturbed. Only where the area has been disturbed by quarrying and similar activities does secondary forest appear. Much of the limestone cliffs are honeycombed with caves. On exposed headlands of Langkawi and Dayang Bunting islands as well as the entire surfaces of some of the rocky islets, the vegetation is often stunted and reduced, the rocks being covered with grasses, bamboos and occasional stunted trees. Only in areas sheltered from the wind is the vegetation more luxuriant with a denser growth of larger trees. Among the common ferns found on the rocky headlands with constant exposure to sea sprays are *Davallia denticulata*, *Pyrrosia* spp., *Drynaria sparsisora* and *Asplenium* spp.

The granite ridges on the other hand have a much softer outline, the vegetation is markedly more luxuriant, consisting of many trees, shrubs, climbers and epiphytes.

Most of the alluvial areas of the coastal plains of Langkawi Island have been cleared and cultivated, and sometimes abandoned. Here the most abundant and conspicuous of all the sun-loving ferns are the well-known ''Resam'' *Dicranopteris linearis* and ''Ribu-ribu'' *Lygodium microphyllum. D. linearis* covers considerable tracts right up to the edges of the forest where it produces dense thickets, while *L. microphyllum* scrambles over other plants, and through the grasses. The rice-fields abound with *Marsilea crenata, Azolla pinnata* and *Ceratopteris thalictroides. C. thalictroides* is also commonly found in irrigation canals. In the mangrove, which covers more than 1474 hectares (nearly 8 per cent of the Island's land surface), the two species of *Acrostichum*, namely *A. aureum* and *A. speciosum* are abundant. On earth banks where exposure to sunlight is maximal, *Nephrolepis biserrata* and *Blechnum orientale* are common.

The plain to the north of Kuah is largely rubber plantation and scattered settlement areas. Here, the common ferns are both terrestrial and epiphytic. *Nephrolepis biserrata* and *Stenochlaena palustris*, with their ability to reproduce vegetatively, flourish. Patches of *D. linearis* are everywhere, especially where the rubber canopy is thin. *Platycerium coronarium*, *P. holttumii*, *Goniophlebium persicifolium*, *Davallia denticulata*, *Drynaria sparsisora*, *D. rigidula*, *Drymoglossum piloselloides*, *Asplenium nidus* and *Vittaria ensiformis* are commonly found as epiphytes on the trunks of *Hevea brasiliensis* as well as on other trees by the Kuah-Kisap Road. *Doryopteris ludens*, *Adiantum latifolium* (introduced from Tropical America but naturalised and widespread not only in Langkawi but also all over Peninsular Malaysia) and *Microlepia speluncae* are abundant on stream banks in the rubber plantations. Besides the two species of *Platycerium* mentioned, the new species *Platycerium platylobum* (Bidin and Jaman, 1986) is only found on this plain, although uncommon. *Helminthostachys zeylanica* and *Schizaea digitata* are very common in lightly shaded areas of the plantation, growing among the grasses. The aerial part of the former is eaten as a vegetable while the rhizomes of both species are used alone or by mixing with other herbs in traditional medicines, supposedly as an aphrodisiac. The most popular vegetable fern (pucuk paku) among the locals is *Stenochlaena palustris.* The reddish juvenile frond is eaten raw or cooked with coconut milk. The fern is abundant in open areas such as settlements, inhabiting wet places, especially stream banks.

Along the tracks leading to "Telaga Tujuh" (Seven Wells) (situated at the extreme western end of Langkawi Island) and Gunung Raya (the highest point on the Island overlooking the town of Kuah) the presence of *Pteris scabripes* with its whitish streaks near the frond margins is very conspicuous. The fern has also been observed on other parts of Langkawi Island but not on any other islands in the group.

Gunung Raya, a granite peak situated in the middle of Gunung Raya Forest Reserve is highly accessible. Most of the collections were made here. It is extremely rich in *Trichomanes*, *Hymenophyllum*, *Asplenium* and *Bolbitis. Bolbitis malaccensis* is elsewhere known only from one collection in Peninsula Thailand and from Tioman Island, on the eastern side of Peninsular Malaysia. *Microlepia strigosa* is found at the summit of Gunung Raya as well as the foot of Malut Hill (c. 100 m) and the collections made constitute the third location for the species recorded for Peninsular Malaysia. Among the members of the family Thelypteridaceae, the genus *Christella* is present from lower elevations (*C. papilio*) right through to the summit of Gunung Raya (*C. subpubescens*).

*Pseudodrynaria coronans* is collected from the Gunung Raya Forest Reserve, near the summit. The plant has its distributional area on the Asian mainland.

In Langkawi and Dayang Bunting it is observed that the sporophyte of some species of ferns (*Cheilanthes tenuifolia* and *Adiantum philippense*) perennate during the dry season especially in January and February by means of their rhizome while the fronds completely die down. Other species maintain at least a few of their leaves in an extremely dehydrated but living state, e.g. *Pyrrosia penangiana* and *Humata pectinata*, both of which are ferns of the limestone rock.

*Drynaria bonii* (a new record for Peninsular Malaysia) is found in Langgun Island only, living epiphytically on stunted trees or on limestone rocks with direct exposure to sunlight and sea sprays. Records at herbaria show that the plant is distributed mainly in Thailand as well as in Indo-China.

Much of Timun Island is inaccessible and the common ferns found on the limestone cliffs are *Adiantum stenochlamys*, *A. caudatum*, *A. philippense*, *Tectaria variolosa* (probably the only location for Malesia (Holttum, pers. comm., 1986, Holttum, 1985), *Drynaria sparsisora* and *Davallia denticulata.*

The genus *Trichomanes* is abundant in Langkawi with eight species, most of them collected in the Gunung Raya Forest Reserve vicinity.

Of the fifteen genera in Thelypteridaceae in Malaya (Holttum, 1980), six are found in Langkawi. All are found in the granite area and mostly in the lowlands. *Pronephrium* is confined to the lowlands only whilst *Amphineuron* and *Christella* are the ferns of lower elevations as well as the mountains. The mountain species are *Amphineuron immersum* and *Christella subpubescens* — both found near the summit of Gunung Raya.

Among the Dennstaedtiaceae, *Lindsaea* (7 spp.) *Pteris* (7 spp.), *Asplenium* (9 spp.) *Tectaria* (5 spp.) are well represented in Langkawi. *Lindsaea* which prefers moist deep shade, is common near the many streams in Gunung Raya Forest Reserve, whilst *Pteris*, *Asplenium* and *Tectaria* inhabit a variety of habitats. As for *Tectaria*, a brief mention should be made of two lowland species namely *T. brachiata* and *T. variolosa,* wrongly united by Holttum (1981b; 137). *T. brachiata* is widely distributed on granite in light shade in Langkawi: it is common in rubber plantations in Kisap as well as in forested areas along trails where the canopy is slightly open. It has a distributional area from NE. India to S. China and Taiwan, Thailand, Vietnam, northern Malaya and Jaya. Holttum (1981b) reported that the species is adapted to a climate with a seasonal dry period, which Langkawi certainly has. It would be interesting to see if the species is present on Tioman Island on the eastern side of Peninsular Malaysia which has a similar climate. *T. variolosa*, a limestone fern which occurs from NE India southwards into Burma, Thailand and Vietnam is found in Langkawi on limestone cliffs and in crevices by the sea on Timun Island. It is a new record for Peninsular Malaysia.

## Ferns of Economic Importance

### Ornamentals

Some of the ferns of Langkawi have also found their way into homes and gardens. Among the popular species are *Asplenium nidus*, *A. phyllitidis*, *Platycerium coronarium*, *Microsorium punctatum* and *Adiantum stenochlamys.* Quite a number of ornamental ferns which are not of local origin are also popular as pot as well as garden plants. These are *Adiantum trapeziforme*, *A. peruvianum*, *A. mathewsianum*, *A. tenerum*, *A. capillus-veneris* and *Nephrolepis biserrata* var. *exaltata.* All are Tropical American ferns which flourish in Langkawi as well as in other parts of the country and which sometimes escape from cultivation and become part of the natural vegetation.

### Other Uses

In the daily life of the Malays in Langkawi, the fern *Lygodium* has a variety of uses. The long climbing rachises are used as twine and said to be long-lasting. Peelings from the rachises are used to make handbags, purses, mats and fish traps.

## List of Ferns Collected and Recorded from Langkawi Islands

The following list of ferns is arranged systematically. For each species the scientific name and the original author with its reference is given. Collection numbers and localities are cited: PL numbers refer to specimens collected during the course of the studies while specimens from herbaria and their collectors are mentioned also. Vernacular names are given where known.

The classification adopted follows Holttum (1968) and his subsequent reappraisal of the families Gleicheniaceae, Schizaeaceae, Cyatheacease and Thelypteridaceae in Flora Malesiana (1959, 1963, 1978, 1981a). Names of *Tectaria* follow Holttum (1981b and 1985), and of *Lindsaea* follow Kramer (1971). Materials I have not seen are indicated by relevant literature citations, while records based upon field identification by the author without voucher specimens being collected are indicated as sight records. All materials collected are lodged in UKMB and duplicates in K (where indicated).

### OPHIOGLOSSACEAE

*Helminthostachys zeylanica* (Linn.) Hook., Gen. Fil. t.47b. 1840.
Paku tunjuk langit; akar paku.

*PL 78*: Kisap; Boon Siew Estate. Terrestrial, in light shade, c. 40 m elevation. UKMB, duplicate at K.

### MARATTIACEAE

*Angiopteris evecta* (Forst.) Hoffm., Comm. Soc. Reg. Gott. 12: 29, t.5. 179b.
Paku gajah.

*PL 122*: Singa Besar Island. Terrestrial, in deep shade, c. 5 m elevation. UKMB.

*PL 281*: Gunung Raya Forest Reserve; Genting Palas, Terrestrial, on slope, in deep shade, c. 550 m elevation. UKMB, duplicate at K.

## SCHIZAEACEAE

*Schizaea dichotoma* (L.) J.E. Smith, Memb. Acad. Turin 5: 442. t.9. 1793; Holttum 1959: 41.
Paku tumbak; paku jarum.

*No. 7145. Md. Haniff & Md. Nur.* Gunung Raya. Terrestrial. 13 November 1921. K.

*Schizaea digitata* (L.) Swartz, Syn. Fil.: 150, 380. t.4. f.1. 1896; Holttum 1959: 41.
Janggut adam; misal ikan keli.

*PL 148*: Road junction of Kampong Buta and Kampong Kubang Badak. Terrestrial, in light shade, c. 90 m elevation. UKMB.

*PL 282*: Gunung Raya Forest Reserve; Genting Palas. Terrestrial, in light shade, c. 550 m elevation. UKMB, duplicate at K.

Kisap; Boon Siew Estate. Terrestrial, in light shade, c. 40 m elevation. Not collected.

*Lygodium polystachyum* Wall. ex Moore, Gard. Chron. 1859: 671; Holttum 1959: 46.

*PL 30*: Bukit Malut Forest Reserve. Terrestrial and scrambling, in light shade, c. 30 m elevation. UKMB, duplicate at K.

*PL 113*: Road to Kuala Temoyong. Terrestrial, in light shade, c. 10 m elevation. UKMB.

*PL 191*: Bumbun Besar Island. Scrambling on bushes, exposed, c. 20 m elevation. UKMB.

*PL 257*: Selat Panchor Forest Reserve; track to Tanjung Apau. Terrestrial, in light shade, c. 110 m elevation. UKMB.

*Lygodium microphyllum* (Cav.) R. Brown, Prod. FI. Nov. Holl: 162. 1810; Holttum 1959: 47.
Ribu-ribu selada; ribu-ribu; salada.

*PL 115*: Kedawang; Kampong Lubuk Buaya. Terrestrial, in light shade, c. 50 m elevation. UKMB, duplicate at K.

*Lygodium flexuosum* (L). Sw., Schrad. J. Bot. 1800(2); 106. 1801; Holttum 1959: 53.
Akar sidin; ribu-ribu gajah; darai paya.

*PL 128*: Seven Wells, by trackside. Scrambling, in light shade, c. 100 m elevation. UKMB.

*PL 180*: Kisap. Terrestrial, on roadside, exposed, c. 30 m elevation. UKMB, 2 sheets.

*Lygodium flexuosum* (L.) Sw. X *Lygodium salicifolium* Presl; Holttum 1959: 53.

*PL 166*: Kampong Sungai Taru. Scrambling on river bank, exposed, c. 20 m elevation. UKMB.

*PL 40*: Kisap; Boon Siew Estate. Scrambling, exposed, c. 40 m elevation. UKMB.

*Lygodium salicifolium* Presl, Suppl, Pterid.: 102, 1845; Holttum 1959: 57.

No. 2739. E.A. Turnau, 5 May 1961. K.

*H.C. Robinson.* Dayang Bunting Island. Terrestrial. November 1916. K.

*PL 29*: Bukit Malut Forest Reserve. Terrestrial, scrambling on *Tremma*, by roadside, in light shade, c. 30 m elevation. UKMB, duplicate at K.

*PL 181*: Gunung Raya Forest Reserve: Lubuk Semilang. Terrestrial, scrambling, in light shade, c. 40 m elevation. UKMB, duplicate at K.

*PL 226*: Kisap; Boon Siew Estate, near Kedah Marble Factory. Terrestrial, scrambling, in light shade, c. 40 m elevation. UKMB.

*Lygodium circinnatum* (Burm.f.) Sw., Syn. Fil.: 153. 1806; Holttum 1959: 59.

Paku jari merah; ribu-ribu duduk; ribu-ribu bukit.

*PL 183*: Kisap; Kuala Kisap. Scrambling, in light shade, c. 5 m elevation. UKMB.

## GLEICHENIACEAE

*Dicranopteris linearis* (Burm.f.) Underw., Bull. Torr. Bot. Cl. 34. 249: 1907. var. *linearis*; Holttum 1959: 33.
Resam.

*PL 92*: Klebang-Ulu Melaka Road. By roadside. Terrestrial, exposed, c. 50 m elevation. UKMB, duplicate at K.

*PL 185*: Kisap; Kuala Kisap. Terrestrial, in light shade, c. 5 m elevation. UKMB.

*Dicranopteris speciosa* (Presl) Holtt., Reinwardtia 4: 273. 1957; Holttum 1959: 32.

*PL 175*: Gunung Raya Forest Reserve: Lubuk Semilang. Terrestrial, in light shade, c. 40 m elevation. UKMB.

## HYMENOPHYLLACEAE

*Hymenophyllum denticulatum* Sw., Schrad. Journ. 1800 (2): 10. 1801.

*No. 7168. Md. Haniff & Md. Nur.* Gunung Raya. Epiphyte. 13 November 1921. K.

*No. 7051. Md. Haniff & Md. Nur.* Gunung Raya. Epiphyte. 13 November 1921. K.

*Trichomanes digitatum* Sw., Syn. Fil. 370. 1806.

*No. 7122. Md. Haniff & Md. Nur.* Gunung Raya. Epiphyte. 13 November 1921. K.

*PL 134*: Gunung Raya Forest Reserve; Durian Perangin Waterfall. On rock, in light shade, c. 200 m elevation. UKMB.

*Trichomanes proliferum* Bl., Enum. Pl. Jav. 224. 1828.

*No. 1064. Md. Haniff.* Telaga Tujuh. Epiphyte. 18 September 1914. K.

*Trichomanes pallidum* Bl., Enum. Jav. 225. 1828.

*PL 217*: Summit of Gunung Raya. On rock, in streambed, in deep shade, c. 950 m elevation. UKMB.

*Trichomanes bipunctatum* Poiret, in Lamarck, Encycl. 8: 60. 1808.

*PL 202*: Gunung Raya Forest Reserve; Genting Palas. On rock, in light shade, c. 800 m elevation. UKMB, duplicate at K.

*Trichomanes latemarginale* Eaton, Proc. Am. Acad. 4: 111. 1859.

*No. 15700. M.R. Henderson.* Adang Island. Epiphyte. 1911. K.

*Trichomanes javanicum* Blume, Enum. Pl. Jav. 224. 1828.

*No. 2433. C. Curtis.* Machinchang. Epiphyte. February 1899. K.

*No. 15699. M.R. Henderson.* Adang Island. Epiphyte. 1911. K.

*No. 15672. M.R. Henderson.* Seven Wells. Epiphyte. 1911. K.

*PL 21*: Bukit Malut Forest Reserve. Terrestrial, in deep shade, c. 160 m elevation. UKMB.

*PL 264*: Gunung Raya Forest Reserve; Sungai Kelian. On rock, in deep shade, c. 150 m elevation. UKMB.

*Trichomanes maximum* Bl., Enum. Pl. Jav. 228. 1828.

*No. 15484. Md. Haniff & Md. Nur.* Gunung Raya. February 1911. K.

*PL 273*: Gunung Raya Forest Reseve; Sungai Kelian. On mossy rock in the middle of Sungai Kelian, in deep shade, c. 460 m elevation. UKMB, duplicate at K.

*Trichomanes obscurum* Bl., Enum. Pl. Jav. 227. 1828.

*PL 209*: Near summit of Gunung Raya. Terrestrial, in deep shade, c. 900 m elevation. UKMB, duplicate at K.

## CYATHEACEAE

*Cyathea contaminans* (Hook.) Copel., Phil. J. Sci. 4c: 60. 1909; Holttum 1963: 135.

*PL 86*: Kisap; Boon Siew Estate. Terrestrial, in light shade, near stream, c. 40 m elevation, UKMB, duplicate at K.

*Cyathea borneensis* Copel., Phil. J. Sci. 6: 135. 1911; Holttum 1963: 110; 1968: 631.

*PL 62*: Near summit of Gunung Raya. Terrestrial, in deep shade, c. 900 m elevation. UKMB, duplicate at K.

*PL 67*: Gunung Raya Forest Reserve; track to summit. Terrestrial, in deep shade, c. 700m elevation. UKMB.

*Cyathea glabra* (Bl.) Copel., Phil. Sci. 4c: 35. 1909; Holttum 1963: 120.

*PL 93*: Gunung Raya Forest Reserve; Lubuk Semilang, near pump-house. On streambank in deep shade, c. 50 m elevation. UKMB, duplicate at K.

*PL 263*: Gunung Raya Forest Reserve; Sungai Kelian. Terrestrial, in deep shade, c. 150 m elevation. UKMB, duplicate at K.

*PL 165*: Gunung Raya Forest Reserve; Lubuk Semilang. Terrestrial, in deep shade, c. 40 m elevation. UKMB, 2 sheets.

## POLYPODIACEAE

*Platycerium coronarium* (Koenig) Desv., Prodr. 213. 1827.
Rumah langsuyar.

*PL 117*: Kisap; Boon Siew Estate. Epiphyte on *Hevea brasiliensis*, in light shade, c. 40 m elevation. UKMB.

*Platycerium holttumii* D. Jonch. & Hennipm., Brit. Fern Gaz. 10, 3. 116: 1970.

*PL 79*: Kisap; Boon Siew Estate: Epiphyte on *Hevea brasiliensis*, in light shade, c. 40 m elevation. UKMB.

*PL 176*: Kisap; Boon Siew Estate. Epiphyte on *Hevea brasiliensis*, in light shade, c. 40 m elevation. UKMB.

*PL 150*: Kisap; Boon Siew Estate (near Kedah Marble Factory). Epiphyte on *Hevea brasiliensis*, in light shade, c. 20 m elevation. UKMB, 2 sheets.

*Platycerium platylobum* Aziz Bidin & Razali Jaman, Gard. Bull. 39(2). pl. 1 & 2. 1986.

*PL 149*: Kampong Padang Lunas. Epiphyte on *Hevea brasiliensis*, in light shade, c. 30 m elevation. UKMB.

*PL 124*: Kisap; Boon Siew Estate. Epiphyte on *Hevea brasiliensis*, in light shade, c. 50 m elevation. Endemic. UKMB.

*Platycerium* sp. (unidentified).

*PL 11*: Bukit Malut Forest Reserve; near proposed dam site. On fallen tree, in light shade, c. 100 m elevation. Endemic. UKMB.

*Pyrrosia adnascens* (Sw.) Ching, Bull. Chin. Bot. Soc. 1: 45. 1935. (Hovenkamp (1986) places both *P. adnascens* and *P. varia* as synonyms of *P. lanceolata* (L) Farwell). Sakat batu; tetumpang.

*PL 37*: Bukit Malut Forest Reserve; near beach. Epiphyte, in light shade, c. 2 m elevation. UKMB.

*PL 169*: Machinchang Forest Reserve; Tanjung Datai. Epiphyte, in light shade, c. 5 m elevation. UKMB.

*PL 287*: Bumbun Besar Island. On rock, exposed, c. 3 m elevation. UKMB.

*PL 154*: Tanjung Rhu. On limestone, exposed, c. 50 m elevation. UKMB.

*Pyrrosia varia* (Kaulf.) Farewell, Am. Midl. Nat. 12: 302. 1931.

*PL 255*: Tanjung Dagu Forest Reserve; track to Tanjung Apau. On rock, in light shade, c. 140 m elevation. UKMB.

*Pyrrosia penangiana* (Hook.) Holtt., Fl. Malaya II. 146–147, pl. 62. 1968. Tanjung Rhu. On limestone by the sea. In light shade, c. 8 m elevation. Slight record, not collected.

*Pyrrosia longifolia* (Burm.) Morton, Wash. Acad. Sci. 36: 168: 1946.

*PL 85*: Kisap; Boon Siew Estate. Epiphyte, in light shade, c. 30 m elevation. UKMB, duplicate at K.

*Pyrrosia stigmosa* (Sw.) Ching, Bull. Chin. Bot. Soc. 1: 67. 1935.

*PL 234*: Dayang Bunting Island. On rock, exposed. c. 5 m elevation. UKMB.

*Drymoglossum piloselloides* (Linn.) Presl, Tent. Pterid. 227. 1836.
Duit-duit; sisik naga; sakat ribu-ribu.
*PL 109*: Kampong Belanga Pecah. Epiphyte, in light shade, c. 30 m elevation. UKMB.

*PL 237*: Kisap; Boon Siew Estate. Epiphyte, in light shade, c. 30 m elevation. UKMB.

*Belvisia mucronata* (Fée) Copel., Gen. Fil. 192. 1947.

*PL 77*: Near summit of Gunung Raya. Epiphyte, in light shade, c. 850 m elevation. UKMB, duplicate at K.

*Loxogramme avenia* (Bl.) Presl, Tent. Pterid. 215. 1836.

*PL 267*: Gunung Raya Forest Reserve; Genting Palas. On mossy rock, in light shade, c. 450 m elevation. UKMB, duplicate at K.

*Microsorium punctatum* (Linn.) Copel, Univ. Cal. Publ. Bot. 16: 111. 1929.

*PL 5*: Bukit Malut Forest Reserve. Epiphyte on *Pandanus*, in light shade, c. 30 m elevation. UKMB.

*PL 177*: Kisap; Boon Siew Estate. Epiphyte on *Hevea brasiliensis*, in light shade; c. 30 m elevation. UKMB, duplicate at K.

*PL 190*: Kisap; Kuala Kisap. Epiphyte on *Hydrocarpus*, in light shade, c. 5 m elevation. UKMB.

*PL 245*: Gunung Raya Forest Reserve; Lubuk Semilang. Epiphyte, in light shade, c. 100 m elevation. UKMB, duplicate at K.

*PL 235*: Dayang Bunting Island, foot of Gua Langsir. On rock, in light shade, c. 10 m elevation. UKMB.

*Microsorium heterocarpum* (Bl.) Ching, Bull. Fan. Mem. Inst. 4: 295. 1933.

*PL 275*: Gunung Raya Forest Reserve; Genting Palas. On rock, in deep shade, c. 50 m elevation. UKMB.

*Colysis acuminata* (Bak.) Holtt., Fl. Malaya II. 162–163. 1968. var. *angustata* Holtt.

*PL 161*: Gunung Raya Forest Reserve; Lubuk Semilang. On rock, in stream bed, in deep shade, c. 50 m elevation. UKMB.

*PL 199*: Gunung Raya Forest Reserve; Genting Palas. On rock, in stream bed, in deep shade, c. 800 m elevation. UKMB, duplicate at K.

*PL 240*: Gunung Raya Forest Reserve; Lubuk Semilang. On rock, in light shade, c. 90 m elevation. UKMB.

*Colysis pedunculata* (Hook. et. Grev.) Ching, Bull. Fan. Mem. Inst. 4: 321. 1933.

*PL 15*: Bukit Malut Forest Reserve. Epiphyte, in deep shade, c. 130 m elevation. UKMB.

*Drynaria sparsisora* (Desv.) Moore, Ind. Fil. 348. 1862.

*PL 36*: Bukit Malut Forest Reserve. Epiphyte, exposed, c. 5 m elevation. UKMB.

*PL 167*: Kampung Sungai Taru; Klebang-Lubuk Semilang Road. Epiphyte, exposed, c. 40 m elevation. UKMB.

*PL 196*: Lentang Jalan Island. On rock, exposed, c. 4 m elevation. UKMB.

*PL 178*: Kisap. Epiphyte, in light shade, c. 30 m elevation. UKMB.

*PL 246*: Gunung Raya Forest Reserve; Lubuk Semilang. Epiphyte, in light shade, c. 100 m elevation. UKMB, duplicate at K.

*Drynaria rigidula* (Sw.) Beddome, Ferns Brit. Ind. t.314. 1869.

*PL 84*: Kisap; Boon Siew Estate. Epiphyte on *Hevea brasiliensis*, in light shade, c. 30 m elevation. UKMB, duplicate at K.

*PL 179*: Kisap; Boon Siew Estate. Epiphyte on *Hevea brasiliensis*, in light shade, c. 30 m elevation. UKMB, duplicate at K.

*Drynaria bonii* Chr., Not. Syst. 1: 186. 1910.

*PL 205*: Langgun Island. On rock, exposed, c. 20 m elevation. Rare. UKMB, duplicate at K. Also collected by Chin (1977). KLU.

*Pseudodrynaria coronans* (Wall.) Ching, Sunyatsenia 5, 4: 262. 1940.

*PL 58*: Gunung Raya Forest Reserve. Epiphyte, in light shade, c. 750 m elevation. UKMB, 2 sheets.

*PL 212*: Near summit of Gunung Raya. Epiphyte, in light shade, c. 800 m elevation. Rare. UKMB.

*Phymatodes nigrescens* (Bl.) J. Smith, Ferns Br. & For. 94. 1966.
Paku sumpah; paku ciai.

*PL 102*: Gunung Raya Forest Reserve; Durian Perangin Waterfall. On rock, exposed, c. 130 m elevation. UKMB.

*PL 244*: Gunung Raya Forest Reserve; Lubuk Semilang. On rock, in light shade, c. 100 m elevation. UKMB, duplicate at K.

*Phymatodes scolopendria* (Burm.) Ching, Contr. Inst. Bot. Nat. Acad. Peiping 2: 63, 1933.

*PL 168*: Machinchang Forest Reserve; Tanjung Datai. Terrestrial, exposed, c. 5 m elvation. UKMB.

*Crypsinus trilobus* (Houtt.) Copel., Gen. Fil. 206. 1947.

*PL 74*: Summit of Gunung Raya. Epiphyte, in light shade. UKMB.

*Lecanopteris sinuosa* Copel., Univ. Calif. Publ. Bot. 16: 123. 1929.

*PL 110*: Kampong Belanga Pecah. Epiphyte by roadside, exposed, c. 30 m elevation. UKMB, duplicate at K.

*Goniophlebium persicifolium* Bedd. 1870 (not in Handb.)

*PL 71*: Near summit of Gunung Raya, Epiphyte, in light shade, associated with *Vittaria* and *Drynaria*, c. 900 m elevation. UKMB, duplicate at K.

*PL 213*: Summit of Gunung Raya. Epiphyte, in light shade, c. 960 m elevation. UKMB, duplicate at K.

## THELYPTERIDACEAE

*Mesophlebion chlamydophorum* (C. Chr.) Holttum, Blumea 22: 321: 1975; Holttum 1981a: 384.

*PL 280*: Gunung Raya Forest Reserve; Genting Palas. Terrestrial, on stream bank, in light shade, c. 550 m elevation. UKMB.

*Cyclosorus interruptus* (Willd.) H. Ito, Bot. Mag. Tokyo 51: 714: 1937; Holttum 1981a: 386.

*PL 256*: Selat Panchor Forest Reserve; track to Tanjung Apau. Terrestrial, in light shade, c. 160 m elevation. UKMB.

*Sphaerostephanos heterocarpus* (Bl.) Holttum in Nayar & Kaur, Compl. to Beddome: 280. 1974; Holttum 1981a: 457.

*PL 286*: Guan Thong Estate. Terrestrial, exposed, c. 20 m elevation. UKMB, duplicate at K.

*Sphaerostephanos penniger* (Hook.) Holttum in Nayar. & Kaur, Compl. to Beddome: 209. 1974; Holttum 1981a: 461.

*PL 53*: Gunung Raya Forest Reserve. Terrestrial, in light shade, c. 650 m elevation. UKMB, duplicate at K.

*RJ 2101 Razali Jaman*: Guan Thong Estate. Terrestrial, in light shade, c. 40 m elevation. UKMB.

*Pronephrium asperum* (Presl.) Holttum, Blumea 20: 112. 1972; Holttum 1981a: 512.

*PL 50*: Gunung Raya Forest Reserve. Terrestrial, near track to summit, in light shade, c. 650 m elevation. UKMB.

*PL 2*: Bukit Malut Forest Reserve. Terrestrial, in light shade, c. 120 m elevation. UKMB.

*PL 101*: Gunung Raya Forest Reserve; Durian Perangin Waterfall. Terrestrial, in light shade, c. 50 m elevation. UKMB.

*PL 129*: Track to Seven Wells. Terrestrial, in light shade, c. 90 m elevation. UKMB, duplicate at K.

*Pronephrium repandum* (Fée) Holttum, Blumea 20: 109. 1972; Holttum 1981a: 533.

*PL 136*: Seven Wells. Terrestrial, on slope, in light shade, c. 200 m elevation. UKMB, duplicate at K.

*PL 262*: Gunung Raya Forest Reserve: Sungai Kelian. Terrestrial, in light shade, c. 150 m elevation. UKMB, duplicate at K.

*Christella papilio* (Hope) Holttum in Nayar & Kaur, Compl. to Beddome, 208. 1974; Holttum 1981a: 556.

*PL 69*: Gunung Raya Forest Reserve. Terrestrial, in light shade, c. 600 m elevation. UKMB, duplicate at K.

*Christella subpubescens* (Bl.) Holttum, Webbia 30: 193. 1976; Holttum 1981a: 558.

*PL 200*: Gunung Raya Forest Reserve: Genting Palas. Terrestrial, on humus-rich stream bank, in deep shade, c. 800 m elevation. UKMB, duplicate at K.

*Christella parasitica* (L.) Lev., Fl. de Kouy-teheou: 475. 1915; Holttum 1981a: 559.

*PL 38*: Guan Thong Estate. Terrestrial, in light shade, c. 20 m elevation. UKMB, duplicate at K.

*PL 10*: Bukit Malut Forest Reserve. Terrestrial, in light shade, c. 100 m elevation. UKMB.

*PL 33*: Bukit Malut Forest Reserve. Terrestrial, in light shade, c. 55 m elevation. UKMB, duplicate at K.

*PL 143*: Machinchang Forest Reserve. Terrestrial, in light shade, c. 90 m elevation. UKMB.

*Christella dentata* (Forsk.) Brownsey & Jermy, Brit. Fern Gaz. 10: 338. 1973; Holttum 1981a: 557.

*PL 17*: Bukit Malut Forest Reserve. Terrestrial, on slope, in light shade, c. 450 m elvation. UKMB, duplicate at K.

*PL 160*: Gunung Raya Forest Reserve; Lubuk Semilang. Terrestrial, in light shade, c. 45 m elevation. UKMB.

*Amphineuron terminans* (Hook.) Holttum, Amer. Fern. 63: 82. 1973; Holttum 1981a: 545.

*PL 18*: Bukit Malut Forest Reserve. Terrestrial, on slope, in light shade, c. 450 m elevation. UKMB, duplicate at K.

*PL 119*: Dayang Bunting Island, track to the lake. Terrestrial, in light shade, c. 5 m elevation. UKMB, duplicate at K.

*PL 236*: Kisap; Boon Siew Estate. Terrestrial, exposed, c. 40 m elevation. UKMB.

*Amphineuron opulentum* (Kaulf.) Holttum, Blumea 19: 45. 1971; Holttum 1981a: 548.

*PL 27*: Bukit Malut Forest Reserve. Terrestrial, in light shade, c. 30 m elevation. UKMB, duplicate at K.

*PL 151*: Gunung Raya Forest Reserve; Kampong Batu Asah. Terrestrial, in light shade, c. 30 m elevation. UKMB.

*Amphineuron immersum* (Bl.) Holttum, in Nayar & Kaur, Compl. to Beddome: 203. 1974; Holttum 1981a: 547.

*PL 22*: Bukit Malut Forest Reserve. Terrestrial, in light shade, c. 120 m elevation. UKMB.

*PL 52*: Near summit of Gunung Raya. Terrestrial, in deep shade, c. 950 m elevation. UKMB, duplicate at K.

## DENNSTAEDTIACEAE

### Dennstaedtioideae

*Microlepia strigosa* (Thb.) Pr., Epimel. Bot. 95. 1849.

*PL 61*: Near summit of Gunung Raya. Terrestrial, in light shade, c. 900 m elevation. UKMB, duplicate at K.

*PL 215*: Summit of Gunung Raya. Terrestrial, in deep shade, c. 950 m elevation. UKMB, duplicate at K.

*Microlepia speluncae* (L.) Index XCIII. 1857. var. *hancei.*

*PL 8*: Bukit Malut Forest Reserve. Terrestrial, exposed, c. 100 m elevation. UKMB, duplicate at K.

*PL 87*: Kisap; Boon Siew Estate. Terrestrial, on stream bank, in light shade, c. 40 m elevation. UKMB, duplicate at K.

*Microlepia speluncae* (L.) Moore, Index XCIII. 1857 var. *villosissima* C. Chr. Gard. Bull. Str. Settl. 4: 399 (1929).

*PL 31*: Bukit Malut Forest Reserve. Terrestrial, in light shade, c. 60 m elevation. UKMB.

*PL 144*: Machinchang Forest Reserve. Terrestrial, exposed, c. 90 m elevation. UKMB.

### Lindsaeoideae

*Lindsaea repens* (Bory) Thwaites, En. Pl. Zeyl.: 388. 1864; Kramer 1971: 237.

H.C. Robinson. Langkawi. November 1916. K.

*PL 158*: Gunung Raya Forest Reserve; Lubuk Semilang. On rock near stream bank, in deep shade, c. 40 m elevation. UKMB.

*PL 278*: Gunung Raya Forest Reserve; Genting Palas. Climbing in deep shade, c. 520 m elevation. UKMB.

*Lindsaea repens* (Bory) Thwaites var. *pectinata* (Blume) Meet. *ex* Kuhn; Kramer 1971: 239.

*PL 278*: Gunung Raya Forest Reserve; Genting Palas. Epiphyte, in deep shade, c. 520 m elevation. UKMB.

*Lindsaea lucida* Bl., Enum. Pl. Jav. 216. 1828; Kramer 1971: 233.

*PL 277*: Gunung Raya Forest Reserve; Genting Palas. On rock near stream bank, in deep shade, c. 520 m elevation. UKMB.

*Lindsaea ensifolia* Sw. Schrad. Journ. 1800/2: 77. 1801; Kramer 1971: 211.

*PL 89*: Kampong Batu Asah. Terrestrial, in light shade, c. 35 m elevation. UKMB.

*PL 132*: Seven Wells. On rock, in light shade, c. 200 m elevation. UKMB.

*Lindsaea heterophylla* Dryand., Trans. Linn. Cos. 3: 41. pl. 8. f. 1. 1791; Kramer 1971: 210.

*PL 20*: Bukit Malut Forest Reserve. Terrestrial, in light shade, c. 200 m elevation. UKMB.

*PL 141*: Machinchang Forest Reseve. Terrestrial, in light shade, c. 200 m elevation. UKMB.

*PL 187*: Kisap; Kuala Kisap. Terrestrial, in light shade, c. 30 m elevation. UKMB.

*Lindsaea parasitica* (Roxburgh *ex* Griffith) Hieron, Hedwigia: 62. 14. 1920; Kramer 1971: 244.

*PL 204*: Near summit of Gunung Raya. Epiphyte, in light shade, c. 900 m elevation. UKMB, duplicate at K.

*Tapeinidium pinnatum* (Cav.) C.Chr., Ind. Fil. 213. 1905; Kramer 1971: 191.

*PL 210*: Near summit of Gunung Raya. Terrestrial, in light shade, c. 950 m elevation. UKMB.

### Davallioideae

*Davallia denticulata* (Burm.) Mett., Kuhn, Fil. Dec. 27. 1867.
Paku tertutup.

*PL 73*: Gunung Raya Forest Reserve. Epiphyte, in light shade, c. 650 m elevation. UKMB.

*PL 156*: Bukit Sawak Forest Reserve. Epiphyte, in light shade, c. 150 m elevation. UKMB.

*PL 174*: Padang Lalang. Epiphyte, exposed, c. 5 m elevation. UKMB, duplicate at K.

*PL 197*: Lentang Jalan Island. On rock, in light shade, c. 6 m elevation. UKMB, duplicate at K.

*PL 232*: Dayang Bunting Island. On rock, by the beach, exposed. UKMB, duplicate at K.

*Davallia trichomanoides* Bl., Enum. Pl. Jav. 238. 1828.

*PL 285*: Track to summit of Gunung Raya. Epiphyte, in deep shade, c. 600 m elevation. UKMB.

*Davallia trichomanoides* Bl. var *lorrainii* (Hance) Holtt.

*PL 216*: Summit of Gunung Raya. Epiphyte, in deep shade, c. 960 m elevation. UKMB, duplicate at K.

*Davallia divaricata* Bl., Enum. Pl. Jav. 237. 1828.

*PL 54*: Gunung Raya Forest Reserve. Epiphyte, in light shade, c. 660 m elevation. UKMB, duplicate at K.

*Humata pectinata* (Sm.) Desv., Prodr. 323. 1827.

Tanjung Rhu. On limesone cliff by the beach, in light shade, c. 8 m elevation. Sight record.

*Humata vestita* (Bl.) Moore, Index XCIII. 1857.

*PL 131*: Seven Wells. On rock in light shade, c. 200 m elevation. UKMB, duplicate at K.

*Humata repens* (L.fil.) Diels, Nat. Pflanzenfam. 1/4: 209. 1899.

*PL 75*: Track to summit of Gunung Raya. Epiphyte, in deep shade, c. 900 m elevation. UKMB.

## Oleandroideae

*Nephrolepis biserrata* (Sw.) Schott, Gen. Fil. ad t. 3. 1834.

*PL 116*: Kedawang; Kampong Lubuk Buaya. Terrestrial, exposed, c. 5 m elevation. UKMB.

*PL 120*: Singa Besar Island. Terrestrial, exposed, c. 5 m elevation. UKMB.

*Nephrolepis biserrata* (Sw.) Schott var. *exaltata.*

Kuah. Ornamental plant. Sight record.

*Nephrolepis hirsutula* (Forst.) Pr., Tent. Pterid. 79. 1836.

*PL 184*: Kisap; Kuala Kisap. Terrestrial, exposed, c. 30 m elevation. UKMB.

*Oleandra pistillaris* (Sw.) C. Chr., Ind. Fil., Suppl. III: 132. 1834.

*PL 214*: Near summit of Gunung Raya. Terrestrial, in light shade, c. 950 m elevation. UKMB.

## Pteridioideae

*Pteris vittata* Linn., Spec. Pl. 2: 1074. 1753.

*PL 83*: Kisap; Boon Siew Estate. Terrestrial, in light shade, c. 30 m elevation. UKMB.

*PL 153*: Kisap. Terrestrial, in light shade, c. 40 m elevation. UKMB.

*Pteris ensiformis* Burm., Fl. Ind. 230. 1768.
Mukut; paku lemukut.

*PL 47*: Kisap; Boon Siew Estate. Terrestrial, in light shade, c. 20 m elevation. UKMB.

*PL 107*: Gunung Raya Forest Reserve; Durian Perangin Waterfall. Terrestrial, in light shade, c. 100 m elevation. UKMB.

*PL 258*: Selat Panchor Forest Reserve; track to Tanjung Apau. Terrestrial, in light shade, c. 110 m elevation. UKMB.

*Pteris scabripes* Wall. apud. Hook., Spec. Fil. 2: 165. 1858.

*No. 3381. C. Curtis.* Foot of Gunung Raya. Terrestrial, April 1896. K.

*No. 15789. M.R. Henderson.* Teluk Barau. Terrestrial. April 1911. K.

*PL 219*: Bukit Sawak Forest Reserve. Terrestrial, in light shade, c. 80 m elevation. UKMB.

*PL 260*: Gunung Raya Forest Reserve: Sungai Kelian. Terrestrial, exposed, c. 55 m elevation. UKMB.

*Pteris venulosa* Bl., Enum. Pl. Jav. 209. 1828.

*PL 127*: Seven Wells. Terrestrial, in deep shade, c. 90 m elevation. UKMB, duplicate at K.

*Pteris biaurita* Linn., Spec. Pl. 2: 1076. 1753.

*No. 6361: H.C. Robinson.* Terutau. November 1916. K.

*No. 29178: R.E. Holttum.* Kisap. 30 November 1931. K.

*PL 41*: Guan Thong Estate. Terrestrial, in light shade, c. 20 m elevation. UKMB.

*PL 88*: Kisap; Boon Siew Estate. Terrestrial, in light shade, c. 40 m elevation. UKMB, duplicate at K.

*PL 142*: Machinchang Forest Reserve. Terrestrial, in light shade, c. 90 m elevation. UKMB, duplicate at K.

*Pteris mertensioides* Willd., Sp. Pl. 5:394. 1810.

*PL 23*: Bukit Malut Forest Reserve. Terrestrial, in light shade, c. 120 m elevation. UKMB.

*Pteris longipinnula* Wall., Cat. No. 108 (nom. nud.); Agardh, Recen. Pterid. 19. 1839.

*PL 48*: Gunung Raya Forest Reserve. Terrestrial, exposed, c. 500 m elevation. UKMB, duplicate at K.

*Acrostichum aureum* Linn., Spec. Pl. 2: 1069. 73. 1753.

Larat; piai lasa; piai raja.

*PL 112*: Kuala Temoyong. In mangrove swamp, c. 0 m elevation. UKMB, duplicate at K.

*Acrostichum speciosum* Willd., Spec. Pl. 5: 117. 1810.

*PL 111*: Kuala Temoyong. In mangrove swamp, by the beach. UKMB, duplicate at K.

*PL 121*: Singa Besar Island. In mangrove swamp, by the beach. UKMB.

*Stenochlaena palustris* (Burm.) Bedd., Ferns Brit. Ind. Suppl. 26. 1876.

*PL 14*: Bukit Malut Forest Reserve. Climbing, in light shade, c. 100 m elevation. UKMB.

### Asplenioideae

*Asplenium nidus* Linn., Spec. Pl. 2: 1079. 1753.
Daun semum; paku langsuyar.

*PL 108*: Gunung Raya Forest Reserve; Durian Perangin Waterfall. Epiphyte, in light shade, c. 140 m elevation. UKMB.

*Asplenium phyllitidis* Don, Prodr. Fl. Nep. 7. 1825.

*PL 13*: Bukit Malut Forest Reserve. Epiphyte, in light shade, c. 100 m elevation. UKMB.

*PL 163*: Gunung Raya Forest Reserve; Lubuk Semilang. Epiphyte on *Knema laurina*, in light shade, c. 50 m elevation. UKMB.

*PL 173*: Machinchang Forest Reserve; Teluk Datai. Epiphyte, in light shade, c. 5 m elevation. UKMB.

*Asplenium phyllitidis* Don subsp. *malesicum* Holttum; Gard. Bull. Sing. 27: 153. 1974.

*PL 70*: Near summit of Gunung Raya. Epiphyte, in light shade, c. 870 m elevation. UKMB, duplicate at K.

*Asplenium salignum* Bl., Enum. Pl. Jav. 175. 1828.

*PL 266*: Gunung Raya Forest Reserve; Genting Palas. On rock, in deep shade, c. 450 m elevation. UKMB, duplicate at K.

*PL 270*: Gunung Raja Forest Reserve; Genting Palas. On rock, in deep shade, c. 450 m elevation. UKMB, duplicate at K.

*Asplenium spathulinum* J. Smith, J. Bot. 3: 408. 1813.

*PL 55*: Gunung Raya Forest Reserve. Epiphyte, in deep shade, c. 720 m elevation. UKMB.

*PL 57*: Near track to summit of Gunung Raya. Epiphyte, in deep shade, c. 750 m elevation. UKMB.

*PL 254*: Tanjung Dagu Forest Reserve. Epiphyte, associated with *A. nidus*, in deep shade, c. 90 m elevation. UKMB, duplicate at K.

*Asplenium pellucidum* Lam., Encyl. 2: 305. 1786.

*PL 241*: Gunung Raya Forest Reserve; Lubuk Semilang. Epiphyte, in deep shade, c. 95 m elevation. UKMB, duplicate at K.

*Asplenium macrophyllum* Sw., Schrad. Journ. 1800/2: 52. 1801.

*PL 182*: Gunung Raya Forest Reserve; Lubuk Semilang. On rock, in light shade, c. 500 m elevation. UKMB.

*PL 233*: Dayang Bunting Island. On rock, in light shade, c. 2 m elevation. UKMB.

*PL 247*: Gunung Raya Forest Reserve; Lubuk Semilang. On rock, in light shade, c. 190 m elevation. UKMB. 2 sheets.

*PL 269*: Gunung Raja Forest Reserve; Genting Palas. On rock, in deep shade, c. 450 m elevation. UKMB, duplicate at K.

*Asplenium tenerum* Forster, Prodr. 80, 1786.

*PL 68*: Near summit of Gunung Raya. Epiphyte, in deep shade, c. 900 m elevation. UKMB, duplicate at K.

*Asplenium paradoxum* Bl., Enum. Pl. Jav. 179. 1828.
*No. 15486. H.N. Ridley.* Gunung Raya. February 1911. K.

**Blechnoideae**

*Blechnum orientale* Linn., Spec. Pl. 2: 1077. 1753.
Paku ikan.

*PL 7*: Bukit Malut Forest Reserve. Terrestrial, on exposed earth bank, c. 100 m elevation. UKMB, duplicate at K.

**Lomariopsidoideae**

*Lomariopsis lineata* (Presl.) Holttum Novit. Bot. Inst. Prag. 1968 (1969) 9; Holttum 1978: 262.

*PL 159*: Gunung Raya Forest Reserve; Lubuk Semilang. On rock, in deep shade, c. 40 m elevation. UKMB.

*Elaphoglossum callifolium* (Bl.) Moore, Ind. Fil. (1857) 7.

*PL 76*: Near summit of Gunung Raya. Epiphyte, in deep shade, c. 900 m elevation. UKMB.

*Bolbitis heteroclita* (Pr.) Ching, in C. Chr., Ind. Fil. Suppl. III, 48. 1934.

*PL 250*: Selat Panchor Forest Reserve. Terrestrial, in deep shade, c. 50 m elevation. UKMB, duplicate at K.

*PL 51*: Gunung Raya Forest Reserve, near track to summit. Climbing, in deep shade, c. 600 m elevation. UKMB.

*PL 66*: Gunung Raya Forest Reserve, near track to summit. Terrestrial, in deep shade, c. 650 m elevation. UKMB.

*PL 251*: Selat Panchor Forest Reserve, track to Tanjung Apau. Climbing in deep shade, c. 50 m elevation. UKMB.

*PL 265*: Gunung Raya Forest Reserve; Sungai Kelian. On rock, in deep shade, c. 50 m elevation. UKMB.

*PL 272*: Gunung Raya Forest Reserve; Genting Palas. On rock, in deep shade, c. 460 m elevation. UKMB.

*Bolbitis malaccensis* (C.Chr.) Ching, in C. Chr., Ind. Fil. Suppl. III, 49. 1934. Langkawi. R.E. Holttum (1968). Rare.

*Bolbitis appendiculata* (Willd.) Iwatsuki, Acta Phytotax. Geobot. 18: 48. 1959. (*Egenolfia appendiculata* in Holttum 1968: 459.).

*PL 12*: Bukit Malut Forest Reserve. On rock, in light shade, c. 100 m elevation. UKMB.

*PL 95*: Gunung Raya Forest Reserve; Lubuk Semilang. On rock, in light shade, c. 50 m elevation. UKMB.

*PL 118*: Dayang Bunting Island. Terrestrial, by trackside to the lake, in light shade, c. 5 m elevation. UKMB.

*PL 130*: Path to Seven Wells. On rock, in light shade, c. 110 m elevation. UKMB.

*PL 140*: Machinchang Forest Reserve. On rock, in deep shade, c. 60 m elevation. UKMB, duplicate at K.

*Bolbitis virens* (Wall.) Schott, Gen. Fil. at t. 14. 1834.
*PL 220*: Bukit Sawak Forest Reserve. On rock, in deep shade, 0.50 m elevation. UKMB.

*PL 276*: Gunung Raya Forest Reserve; Genting Palas. Terrestrial, in deep shade, c. 500 m elevation. UKMB. 2 sheets.

**Dryopteridoideae**

*Polystichum prolificans* V.A.V.R., Bull. Jard. Bot. Buitenz., III ser., 2: 170. 1920.
*PL 72*: Near summit of Gunung Raya. Terrestrial, in deep shade, c. 900 m elevation. UKMB, duplicate at K.

**Tectarioideae**

*Tectaria brachiata* (Zoll. & Mor.) Morton, Contr. U.S. Nat. Herb. 38. 217. 1973; Holttum 1981b: 137, excl. *Aspidium variolosum* and its synonyms.

*PL 24*: Bukit Malut Forest Reserve. Terrestrial, in light shade, c. 120 m elevation. UKMB.

*PL 34*: Bukit Malut Forest Reserve. Terrestrial, in light shade, c. 10 m elevation. UKMB, duplicate at K.

*PL 45*: Kisap; Boon Siew Estate. Terrestrial, in light shade, c. 20 m elevation. UKMB, duplicate at K.

*PL 97*: Ulu Melaka; Kampong Bukit Hantu. Terrestrial, in light shade, c. 60 m elevation. UKMB, duplicate at K.

*Tectaria variolosa* (Hook.) C. Chr., Contr. U.S. Nat. Herb. 26 (1931) 289.

*PL 222*: Timun Island, Tanjung Timun. In rock crevices, exposed to sunlight and sea-sprays, c. 6 m elevation. UKMB, duplicate at K. Rare.

*Tectaria semipinnata* (Roxb.) Morton, Contr. U.S. Nat. Herb. 38 (1974) 286. (*T. maingayi* in Holttum 1981b: 513).

*PL 49*: Gunung Raya Forest Reserve. Terrestrial, in light shade, c. 650 m elevation. UKMB, duplicate at K.

*PL 100*: Gunung Raya Forest Reserve; Durian Perangin Waterfall. Terrestrial, in light shade, c. 50 m elevation. UKMB, duplicate at K.

*Tectaria angulata* (Willd.) Copel., Sarawak Mus. J. 2: 370. 1917.

*PL 164*: Gunung Raya Forest Reserve; Lubuk Semilang, near pumphouse. Terrestrial, in light shade, c. 40 m elevation. UKMB.

*PL 123*: Singa Besar Island. Terrestrial, in light shade, c. 7 m elevation. UKMB.

*Tectaria rumicifolia* (Ridley) C. Chr. in Holttum 1968: 519, 636; *T. oligophylla* (Rosenst.) C. Chr.

*PL 137*: Machinchang Forest Reserve. Terrestrial, on slope, in deep shade, c. 240 m elevation. UKMB, duplicate at K.

*Cyclopeltis crenata* (Fée) C. Chr., Ind. Fil. Suppl. 64. 1934.

*PL 253*: Tanjung Dagu Forest Reserve; track to Tanjung Apau. Terrestrial, in deep shade, c. 60 m elevation. UKMB, duplicate at K.

*Arcypteris irregularis* (Pr.) Holtt., Reinwardtia 1: 193. 1951.

*PL 82*: Kisap; Boon Siew Estate, track to Gunung Raya. Terrestrial, in light shade, c. 30 m elevation. UKMB, duplicate at K.

*Ctenitis mannii* (Hope) Ching, Bull. Fan. Mem. Inst. Bot. 8: 289. 1938.

*PL 201*: Gunung Raya Forest Reserve; Genting Palas. On rock, in light shade, c. 800 m elevation. UKMB, duplicate at K.

*Ctenitis subobscura* (Christ) Holttum, Fern Gaz. 12: 320 (1934); Blumea 31: 23 (1985).

*No. 15548. Md. Haniff.* Gunung Raya. 1911. K.

### Athyrioideae

*Diplazium esculentum* (Retz) Sw., Schrad. J. Bot. 1801/2: 312. 1803; Holttum 1968, App. II: 637.
Paku besar.

*PL 125*: Kuah; Kampong Padang Lalung. Terrestrial, in swamp, exposed, c. 50 m elevation. UKMB.

*Diplazium malaccense* Pr., Epim. Bot. 86. 1849; Holttum 1968, App. II: 637.

*PL 207*: Near summit of Gunung Raya. Terrestrial, in light shade, c. 950 m elevation. UKMB, duplicate at K.

*Diplazium bantamense* Bl., Enum. Pl. Jav. 191. 1828; Holttum 1968, App. II: 637.

*PL 60*: Track to summit of Gunung Raya. Terrestrial, in deep shade, c. 900 m elevation. UKMB.

## ADIANTACEAE

*Ceratopteris thalictroides* (Linn.) Brongn., Bull. Soc. Philon. 1821: 86.
Paku dodok.

*PL 14*: Kampong Kubang Badak. In rice-field, c. 5 m elevation. UKMB.

*PL 90*: Kampong Batu Asah. On stream-bed, in light shade, c. 30 m elevation. UKMB.

*PL 114*: Kampong Lubuk Buaya. In mud, exposed, c. 5 m elevation. UKMB, duplicate at K.

*PL 147*: Kampong Kubang Badak. In rice-field, c. 5 m elevation. UKMB.

*PL 224*: Kisap; Boon Siew Estate. In mud, exposed, c. 30 m elevation. UKMB.

*Taenitis blechnoides* (Willd.) Sw., Syn. Fil. 24, 220. 1806.
Paku bulu.

*PL 3*: Bukit Malut Forest Reserve. Terrestrial, in light shade, c. 100 m elevation. UKMB.

*PL 4*: Bukit Malut Forest Reserve. Terrestrial, in light shade, c. 100 m elevation. UKMB.

*PL 135*: Seven Wells. Terrestrial, on stream bank, in light shade, c. 200 m elevation. UKMB.

*PL 261*: Gunung Raya Forest Reserve; Genting Palas. Terrestrial, in light shade, c. 100 m elevation. UKMB.

*PL 283*: Gunung Raya Forest Reserve; Genting Palas. Terrestrial, in light shade, c. 550 m elevation. UKMB.

*No. 15786: M.R. Henderson.* Teluk Barau. April 1911. K.

*Cheilanthes tenuifolia* (Burm.) Sw., Syn. Fil. 129, 332. 1806.
Resam padi; temangah; telur belangkas.

*No. 2039. Abdul Samat Abdullah.* Kuah. KLU, duplicate at K.

*PL 43*: Kisap; Boon Siew Estate. Terrestrial, in light shade, c. 20 m elevation. UKMB, duplicate at K.

*PL 138*: Kampong Kubang Badak. Terrestrial, exposed, c. 40 m elevation. UKMB.

*Pityrogramma calomelanos* (L.) Link, Handb. Gew: 3:20. 1833.
Paku hijau.

*PL 9*: Bukit Malut Forest Reserve. Terrestrial, exposed, c. 100 m elevation. UKMB.

*Doryopteris ludens* (Wall.) J. Sm., Hist. Fil. 289. 1875.

*H.C. Robinson.* Dayang Bunting Island. November 1916. K.

*No. 29066. M.R. Henderson.* Selat Panchor, c. 50 m elevation. November 1934. K.

*PL 46*: Kisap; Boon Siew Estate. Terrestrial, in light shade, c. 20 m elevation. UKMB.

*PL 221*: Timun Island. In rock crevices, c. 1 m elevation. UKMB.

*Hemionitis arifolia* (Burm.) Moore, Ind. Fil. 114. 1859.

*PL 32*: Bukit Sawak Forest Reserve. On rock, in light shade, c. 50 m elevation. UKMB.

*PL 46*: Kisap; Boon Siew Estate. Terrestrial, in light shade, c. 20 m elevation. UKMB, duplicate at K.

*PL 225*: Kisap; Boon Siew Estate, near Kedah Marble Factory. Terrestrial, in light shade, c. 30 m elevation. UKMB.

*Adiantum stenochylamys* Bak., Am. Bot. 5: 29. 1891.

*No. 15788. M.R. Henderson.* Teluk Barau. April 1911. K.

Timun Island. On rock, exposed, c. 6 m elevation. Not collected. Sight record.

*Adiantum caudatum* Linn., Mantissa 308. 1771.

*PL 230*: Dayang Bunting Island. Terrestrial, in light shade, c. 10 m elevation. UKMB, duplicate at K.

*Adiantum philippense* Linn., Spec. Pl. 2: 1094. 1753.
Paku sisik; paku mega.

*No. 29074. M.R. Henderson.* Selat Panchor, c. 100 m elevation. 23 November 1934. K.

*PL 44*: Kisap; Boon Siew Estate. Terrestrial, in light shade, c. 70 m elevation. UKMB; duplicate at K.

*PL 229*: Timun Island; Tanjung Timun. In rock crevices, exposed, c. 6 m elevation. UKMB, duplicate at K.

*PL 231*: Dayang Bunting Island. Terrestrial, in light shade, c. 10 m elevation. UKMB, duplicate at K.

*Adiantum capillus-veneris* Linn., Spec. Pl. 2: 1096. 1753.
Kuah. Ornamental plant. Sight record.

*Adiantum mathewsianum* Hook., Sp. Fil. 2: 35. 1858.
Kuah. Ornamental plant. Sight record.

*Adiantum peruvianum* Kl., Linnaea 18: 555. 1845.
Kuah. Ornamental plant. Sight record.

*Adiantum trapeziforme* Linn., Spec. Pl. 2: 1097. 1753.
Kuah. Ornamental plant. Sight record.

*Adiantum tenerum* Swartz., Prodromus 135. 1788.
Kuah. Ornamental plant. Sight record.

*Adiantum latifolium* Lam, Encycl. 1: 43. 1783.

*PL 42*: Kisap; Boon Siew Estate. Terrestrial, in light shade, c. 20 m elevation. UKMB.

*PL 81*: Kisap; Boon Siew Estate. Terrestrial, in light shade, c. 30 m elevation. UKMB.

*Adiantum polyphyllum* Willd., Sp. Pl. 5: 454. 1828.
Kuah. Ornamental plant. Sight record.

*Antrophyum callifolium* Bl., Enum. Pl. Jav. III. 1828.

*No. 6359. H.C. Robinson.* Terutau. April 1911. K.

*PL 16*: Bukit Malut Forest Reserve. On rock, in light shade, c. 500 m elevation. UKMB, duplicate at K.

*PL 103*: Gunung Raya Forest Reserve; Durian Perangin Waterfall. On rock, in deep shade, c. 100 m elevation. UKMB.

*PL 242*: Gunung Raya Forest Reserve; Lubuk Semilang. On rock, in light shade, c. 100 m elevation. UKMB, duplicate at K.

*PL 274*: Gunung Raya Forest Reserve; Genting Palas. On rock, in deep shade, c. 500 m elevation, UKMB.

*Vittaria ensiformis* Sw., Ges. Nat. Fr. Berl. Neu. Schr. 2: 134, t. 7. f. 1. 1799.

*No. 15831. H.C. Robinson.* Pulau Adang: April 1911. K.

*PL 106*: Gunung Raya Forest Reserve; Durian Perangin Waterfall. Epiphyte, exposed, c. 100 m elevation. UKMB, duplicate at K.

*PL 139*: Machinchang Forest Reserve. Epiphyte on *Pentacalyx*, in light shade, c. 50 m elevation. UKMB.

*PL 172*: Machinchang Forest Reserve; Teluk Datai. Epiphyte, in light shade, c. 5 m elevation. UKMB, duplicate at K.

*Vittaria ensiformis* Sw. var. *latifolia* Holttum.

*PL 56*: Gunung Raya Forest Reserve. Epiphyte, in light shade, c. 720 m elevâtion. UKMB. 2 sheets.

*PL 193*: Bumbun Besar Island. On rock, exposed, c. 3 m elevation. UKMB.

*Vittaria angustifolia* Bl., Enum. Pl. Jav. 199. 1828.

*PL 249*: Gunung Raya Forest Reserve; Lubuk Semilang. Epiphyte, in light shade, c. 90 m elevation. UKMB.

### MARSILEACEAE

*Marsilea crenata* Presl, Rel-Haenk. 1: 84, t. 12, f. 13. 1825.

*PL 98*: Hulu Melaka; Kampong Bukit Hantu. In rice-field, exposed, c. 50 m elevation. UKMB, duplicate at K.

*PL 99*: Hulu Melaka; Kampong Bukit Hantu. In rice-field, exposed, c. 50 m elevation. UKMB, duplicate at K.

*PL 146*: Kampong Kubang Badak. In rice-field, exposed, c. 5 m elevation. UKMB.

### AZOLLACEAE

*Azolla pinnata* R. Br., Prodr. Fl. N. Holl. 167. 1810.

Hulu Melaka; Kampong Bukit Hantu. In rice-field, exposed, c. 5 m elevatior Sight record.

The breakdown of the fern flora is as shown in Table 1 below:

Table 1

Breakdown of the Langkawian Fern Flora.

| Families/Subfamilies | Genera | No. of species (incl. subspecies, varieties and hybrids) |
|---|---|---|
| OPHIOGLOSSACEAE | *Helminthostachys* | 1 |
| MARATTIACEAE | *Angiopteris* | 1 |
| SCHIZAEACEAE | *Schizaea* | 2 |
| | *Lygodium* | 6 |
| GLEICHENIACEAE | *Dicranopteris* | 2 |
| HYMENOPHYLLACEAE | *Hymenophyllum* | 1 |
| | *Trichomanes* | 8 |
| CYATHEACEAE | *Cyathea* | 3 |
| POLYPODIACEAE | *Platycerium* | 4 |
| | *Pyrrosia* | 5 |
| | *Drymoglossum* | 1 |
| | *Belvisia* | 1 |
| | *Loxogramme* | 1 |
| | *Microsorium* | 2 |
| | *Colysis* | 2 |
| | *Drynaria* | 3 |
| | *Pseudodrynaria* | 1 |
| | *Phymatodes* | 2 |
| | *Crypsinus* | 1 |
| | *Lecanopteris* | 1 |
| | *Goniophlebium* | 1 |

*Table 1 (Contd)*

| Families/Subfamilies | Genera | No. of species (incl. subspecies, varieties and hybrids) |
|---|---|---|
| THELYPTERIDACEAE | *Mesophlebion* | 1 |
| | *Cyclosorus* | 1 |
| | *Sphaerostephanos* | 2 |
| | *Pronephrium* | 2 |
| | *Christella* | 4 |
| | *Amphineuron* | 3 |
| DENNSTAEDTIACEAE | | |
| Dennstaedtioideae | *Microlepia* | 3 |
| Lindsaeoideae | *Lindsaea* | 7 |
| | *Tapeinidium* | 1 |
| Davallioideae | *Davallia* | 4 |
| | *Humata* | 3 |
| Oleandroideae | *Nephrolepis* | 3 |
| | *Oleandra* | 1 |
| Pteridioideae | *Pteris* | 7 |
| | *Acrostichum* | 2 |
| | *Stenochlaena* | 1 |
| Asplenioideae | *Asplenium* | 9 |
| Blechnoideae | *Blechnum* | 1 |
| Lomariopsidoideae | *Lomariopsis* | 1 |
| | *Elaphoglossum* | 1 |
| | *Bolbitis* | 4 |
| Dryopteridoideae | *Polystichum* | 1 |
| Tectarioideae | *Tectaria* | 5 |
| | *Cyclopeltis* | 1 |
| | *Arcypteris* | 1 |
| | *Ctenitis* | 2 |
| Athyrioideae | *Diplazium* | 3 |
| ADIANTACEAE | *Ceratopteris* | 1 |
| | *Taenitis* | 1 |
| | *Cheilanthes* | 1 |
| | *Pityrogramma* | 1 |
| | *Doryopteris* | 1 |
| | *Hemionitis* | 1 |
| | *Adiantum* | 10 |
| | *Antrophyum* | 1 |
| | *Vittaria* | 3 |
| MARSILEACEAE | *Marsilea* | 1 |
| AZOLLACEAE | *Azolla* | 1 |
| | Total number: 59 | Total number: 145 |

## Conclusion

The Langkawian fern flora consists of some 134 species, 2 subspecies, 8 varieties and 1 hybrid representing about 29% of the total number of species found in Peninsular Malaysia, and comprising diverse elements of Malesia, Indochina, India, and Tropical America (introduced).

The introduced elements (some escaped from cultivation and successfully forming part of the natural vegetation, e.g. *Adiantum latifolium*, number only 7 (six of them belong to the genus *Adiantum*) or 4.8% of the total fern flora of Langkawi. Some of the species which have their centre of distribution in mainland Asia have their southern limit in Langkawi as exemplifed by *Platycerium holttumii*, *Pseudodrynaria coronans* and *Tectaria variolosa*. Ferns which may be absent from mainland Malaysia occur in Langkawi due to the preference for a seasonal climate, e.g. *Bolbitis malaccensis* and *Adiantum philippense*. It is apparent from the number of species collected and recorded that Langkawi is rich in its fern flora — thanks to its favourable climate and the varied habitats available.

The stunning beauty of the islands and the cool, refreshing and pollution-free air and sea in Langkawi, have encouraged the authorities to put forward a plan to develop a massive resort city on the north-east portion of the main island, covering c. 566 hectares, centred around a crescent-shaped beach near Tanjung Rhu, as well as at a few other places in this group of islands. The construction of roads, airport, hotels, etc., have already started. The after-effects, such as erosion and landslips, are indeed posing a real threat to the indigenous vegetation not only in terms of area depletion but also extensive degradation and invasion of exotic plants. With these activities, it is becoming apparent that the flora and fauna of Langkawi urgently require investigations before the primary character becomes drastically modified. As survival depends upon preservation of their habitats, conservation of the existing nature reserves is of the utmost importance.

## Acknowledgements

The author is grateful to Prof. R.E. Holttum for his guidance in the identification of some of the specimens, to the Keeper and Curator of the Herbaria at Royal Botanic Gardens Kew and University of Malaya respectively for the use of materials and to the staff of the Office of Forest, Langkawi for allowing the author to carry out a survey of the ferns of Langkawi Islands. The field work was supported by Universiti Kebangsaan Malaysia, Research Grant No. 123/85. The author also wishes to thank Encik-Encik Razali Jaman, Ahmad Zainuddin and A. Hamid for their competent assistance in the field.

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# MSMA for Controlling *Cyperus kyllingia, Axonopus compressus* and *Brachiara distachya* in Tifgreen Bermuda Grass Turf

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## Abstract

Several herbicides were tested for selective control of grass and broadleaf weeds in Tifgreen Bermuda grass turf in golf courses. MSMA (monosodium methanearsonate) was found to selectively control *Cyperus kyllingia, Axonopus compressus and Brachiara distachya*, three of the most troublesome weeds in the golf courses. Metribuzin selectively controlled *Euphorbia thymifolia.*

## Introduction

The high frequency of mowing, together with the low cutting height in golf courses should be expected to keep many species of weeds under control. However, there are those weeds which can thrive even under close mowing because they have leaf forms that lie under the cutting blade. These if left unchecked can intermingle and eventually take over the sward from the finer grasses (Ellis 1986). At a point where manual weeding cannot keep up with spread of such hardy weeds, use of selective herbicides may be the alternative.

In the use of herbicides various factors need consideration, perhaps the most important being the control of weeds without excessive damage to the turf. Johnson (1983) reported that some herbicides like napropamide and prosulfalin reduced root growth of Bermuda grass. Ability to resist herbicide damage was found to differ among turfgrasses eg. among the triploid hybrid Bermuda grasses, Tifway hybrids exceed the Tifgreen hybrids in tolerance to 2,4-D (Hanna 1986).

Examples of chemical weed control in Bermuda grass include the use of diclofop for controlling goosegrass (*Eleusine indica*) in Tifdwarf putting greens (Murdock and Nishimoto 1982). Batten (1984) reported the control of goosegrass by post-emergence applications of MSMA or metribuzin. Sedges such as the purple nutsedge were reported to be controlled post-emergence on the basis of a continual reduction of the leaves and plant with repeated MSMA or bentazon applications; as new shoots recur from rhizomes and tubers, another herbicide application will reduce them. MSMA, especially effective in controlling established Johnsongrass, was applied repeatedly between three to eight times per growing season in order to achieve effective control (Anderson 1977).

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Weeds invading Bermuda grasses used in the Serapong Golf Course of Sentosa and Tanah Merah Golf Course were described by Wong (1986). This paper reports the experiments carried out to control some of these weeds in the Tifgreen Bermuda grass fairways and driving range of the Golf Courses.

## Materials and Methods

Apart from herbicides which were already available to the experimentor, 12 locally-based agrochemical companies were also requested to recommend selective herbicides for use in Bermuda grass swards. Response was limited but a total of five herbicides were finally chosen for the trial. They were metribuzin (Sencor WP 70), dicamba (Fez PE 400), bentazon (Basagran 39.6%), 2,4-D (2,4-D amine 720), and MSMA (MSMA 500).

Trials on Tifgreen Bermuda grass and weeds were conducted separately to determine the effects of the various herbicides on each. Trials on Tifgreen Bermuda grass were conducted in relatively weed free areas in a fairway at the Serapong Golf Course and those on weeds in the Tanah Merah Golf Course driving range. The weeds initially monitored were *Axonopus compressus, Cyperus kyllingia*, and *Euphorbia thymifolia. Brachiara distachya* was included at a later stage.

The randomised complete block design was used for each trial. The five herbicides were each tested at 4 levels of concentration. They were:- metribuzin (Sencor WP 70) — 0, 0.2, 0.6 and 1.2 g/1; dicamba (Fez Pe 400) — 0, 1.0, 2.0 and 3.0 ml/l; bentazon (Basagran 39.6%) — 0, 2.0, 6.0 and 10.0 ml/l; 2,4-D (2,4-D amine 720) — 0, 2.0, 4.0 and 8.0 ml/l; MSMA (MSMA 500) — 0, 2.0, 6.0 and 10.0 ml/l. In each trial, 3 blocks containing 20 treatment plots each were constructed; each treatment plot was 0.4 m by 0.4 m in size. Treatments were completely randomised within each block.

Application of herbicide was carried out using Gardena pressure sprayers. Each treatment plot was sprayed with 100 ml herbicide with teepol added as wetting agent.

Effects of herbicides on turf and weeds were monitored after herbicide application by recording visual ratings of phytotoxicity, adopting the method used by Murdoch and Nishimoto (1982). In the case of Tifgreen Bermuda grass, ratings were based on a scale of 1–10 with ‘1’ being no phytotoxicity and ‘10’ being complete kill of turf. For weeds, ‘1’ meant no control of weeds while a ‘10’ rating meant complete weed control. Visual ratings were recorded by the same person throughout. Results presented below are all average readings of three blocks/replications.

## Results and Discussion

Phytotoxicity or weed control ratings in each trial were monitored for a period of one month. Ratings of phytotoxicity for Bermuda grass were based on a scale of 1–10. Ratings of ‘1’ and ‘2’ are to be considered as showing no phytotoxicity; in some instances ‘imperfections’ in the turf were caused by slight scalping during mowing etc and a rating of ‘2’ instead of ‘1’ was given. Ratings of ‘3’ and ‘4’ indicate mild phytotoxicity and ‘5’ shows 50% turf burn. Ratings of ‘6’ and ‘7’ indicate increasing levels of unacceptable burn while plots given ratings of ‘8’ and above were very badly burnt and unsightly.

Phytotoxicity symptoms in Bermuda grass, when they occurred, were in most cases very quickly apparent i.e. within two days from herbicide application (Fig. 1). It was also found that in most cases, turf that were burnt to ratings of ‘7’ and above were able to recover to ratings of ‘4–6’ within a month from herbicide application. It must be noted though that the seemingly rapid recovery from burn was probably due to

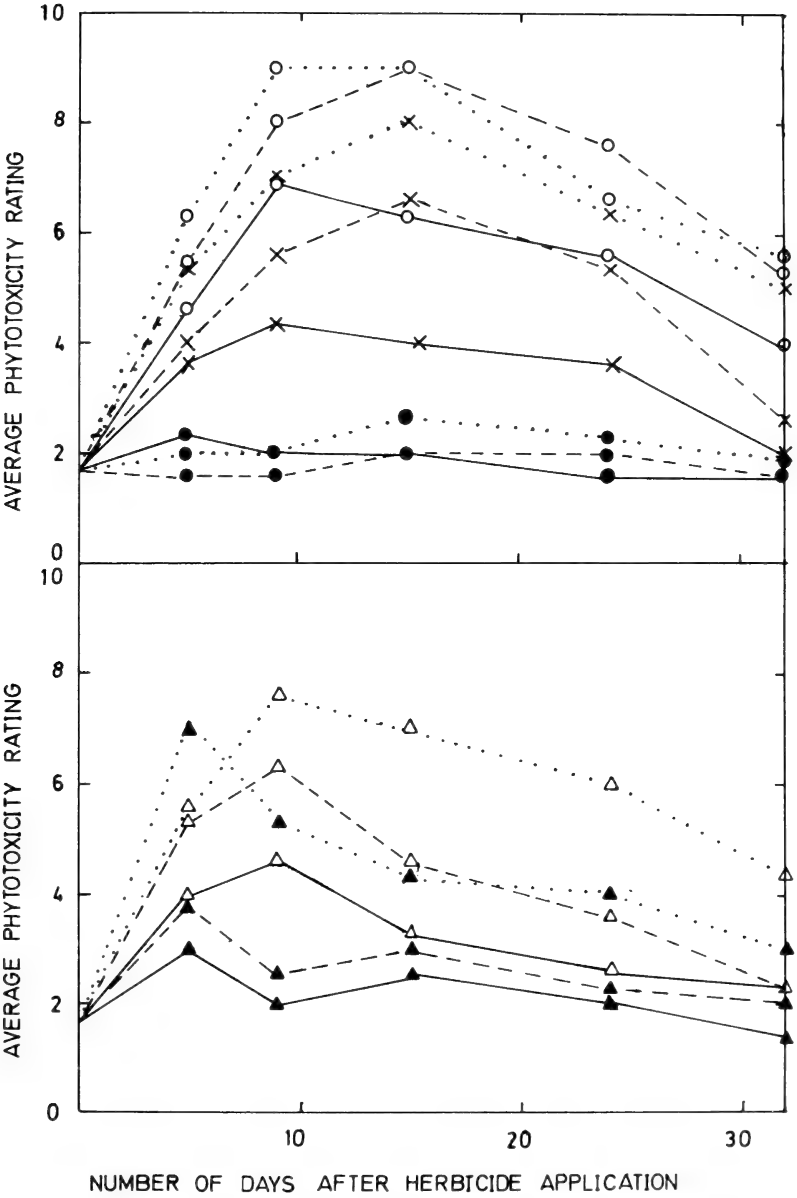

Fig. 1. Effects of herbicides on Tifgreen Bermuda grass.

Each herbicide was tested at four levels of concentration with 0 ml or 0 g/l as controls against which the effects of other treatments were compared. Herbicides were applied once at the start of the trial after which turf quality was monitored. This is expressed as phytotoxicity ratings on a scale of 1–10 where '1' means no phytotoxicity symptoms and '10' means complete killing of turf. Results presented are averages of three blocks/replicates. Herbicide concentrations are represented by the following symbols:-

(×————×), (×---------×), (×.........×) — metribuzin (Sencor WP 70) at 0.2, 0.6 and 1.2 g/l respectively; (○————○), (○---------○), (○.........○) — dicamba (Fez PE 400) at 1.0, 2.0 and 3.0 ml/l; (●————●), (●---------●), (●.........●) — bentazon (Basagran 39.6%) at 2.0, 6.0 and 10.0 ml/1; (△————△), (△---------△), (△.........△) — 2,4-D (2,4-D amine 720) at 2.0, 4.0 and 8.0 ml/l; (▲————▲), (▲---------▲), (▲.........▲) — MSMA (MSMA 500) at 2.0, 6.0 and 10.0 ml/l.

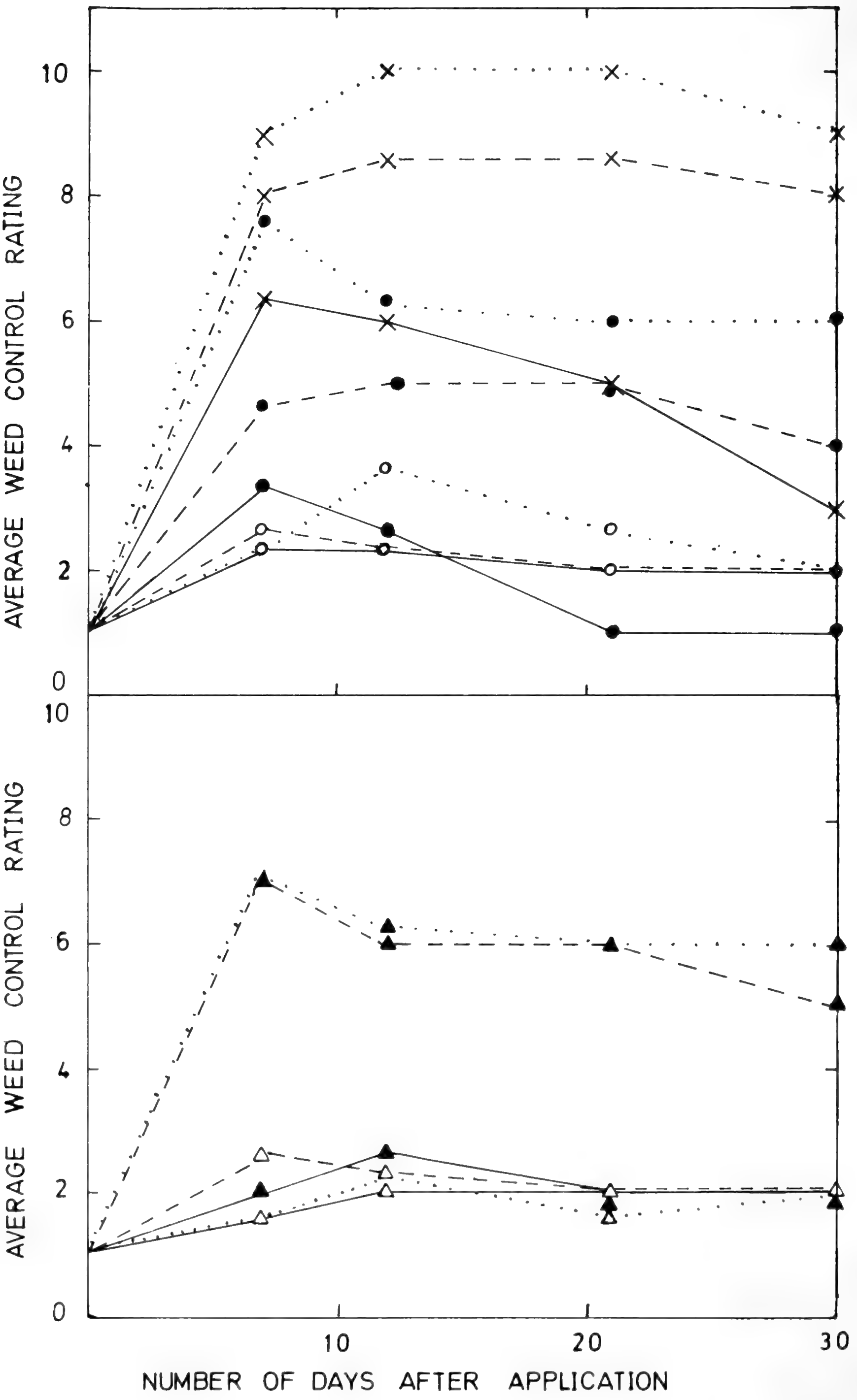

Fig. 2. Effects of herbicides on *Cyperus kyllingia*.
The procedure for this trial and symbols for herbicides and concentrations are as found in Fig. 1. Weed control was expressed as weed control ratings of 1–10, with '1' meaning no control and '10' meaning total killing of weeds. Results presented are averages of three blocks/replicates.

the fact that even when most of the turf within a treatment plot was killed, turf surrounding it continued to grow, sending new shoots into the damaged plot. Thus recovery from herbicide burn of ratings '7' and above, under trial conditions, should not be taken to mean that the same will be expected to occur if large areas of turf were blanket sprayed with overdoses of herbicides. Spot spraying appears to be the safer method of application and if blanket spraying is to be carried out then lower dosages of herbicide should be used, repeating the application when necessary.

Results shown in Fig. 1 are summarised in Table 1 which shows herbicide concentrations that produced phytotoxicity ratings of '4' and below in Bermuda grass. The rating of '4' was chosen as the upper limit for acceptable turf because the visual appearance of grass with this rating and below was reasonably good and recovery from the effects of herbicide was rapid. With this as the criterion it is seen that metribuzin WP70 at 0.2 g/l, bentazon 39.6% at 2.0, 6.0 and 10.0 ml/l, and MSMA 500 at 2.0 and 6.0 ml/l could be 'safely' sprayed on Tifgreen Bermuda grass.

Table 1
Herbicide concentrations that could be 'safely' used on Tifgreen Bermuda grass.

| Herbicide | | Tifgreen Bermuda grass |
|---|---|---|
| Metribuzin (Sencor WP 70) g/l | 0.2 | x |
| | 0.6 | |
| | 1.2 | |
| Dicamba (Fez PE 400) ml/l | 1.0 | |
| | 2.0 | |
| | 3.0 | |
| Bentazon (Basagran 39.6%) ml/l | 2.0 | x |
| | 6.0 | x |
| | 10.0 | x |
| 2,4-D (2,4-D amine 720) ml/l | 2.0 | |
| | 4.0 | |
| | 8.0 | |
| MSMA (MSMA 500) ml/l | 2.0 | x |
| | 6.0 | x |
| | 10.0 | |

Concentrations of herbicides that caused burn up to a upper limit of phytotoxicity rating '4' are marked (X); these are considered 'safe' for use on the turf under the experimental conditions employed. Results shown here are extracted from data in Fig. 1. Plots of turf showing phytotoxicity ratings of '4' and below were not excessively unsightly and recovered from burn rapidly.

Figures 2–4 show the effects of herbicides on *Cyperus kyllingia, Euphorbia thymifolia* and *Axonopus compressus* respectively. Weeds that were controlled at ratings of '1–5' were found to recover quickly from the effects of the herbicides. Increasingly effective control was noted with ratings of '6–8' while in cases where ratings of '9–10' were achieved, excessive damage to Bermuda grass also occurred. Herbicide concentrations that resulted in control ratings of '7' were therefore considered potentially useful for selective weed control.

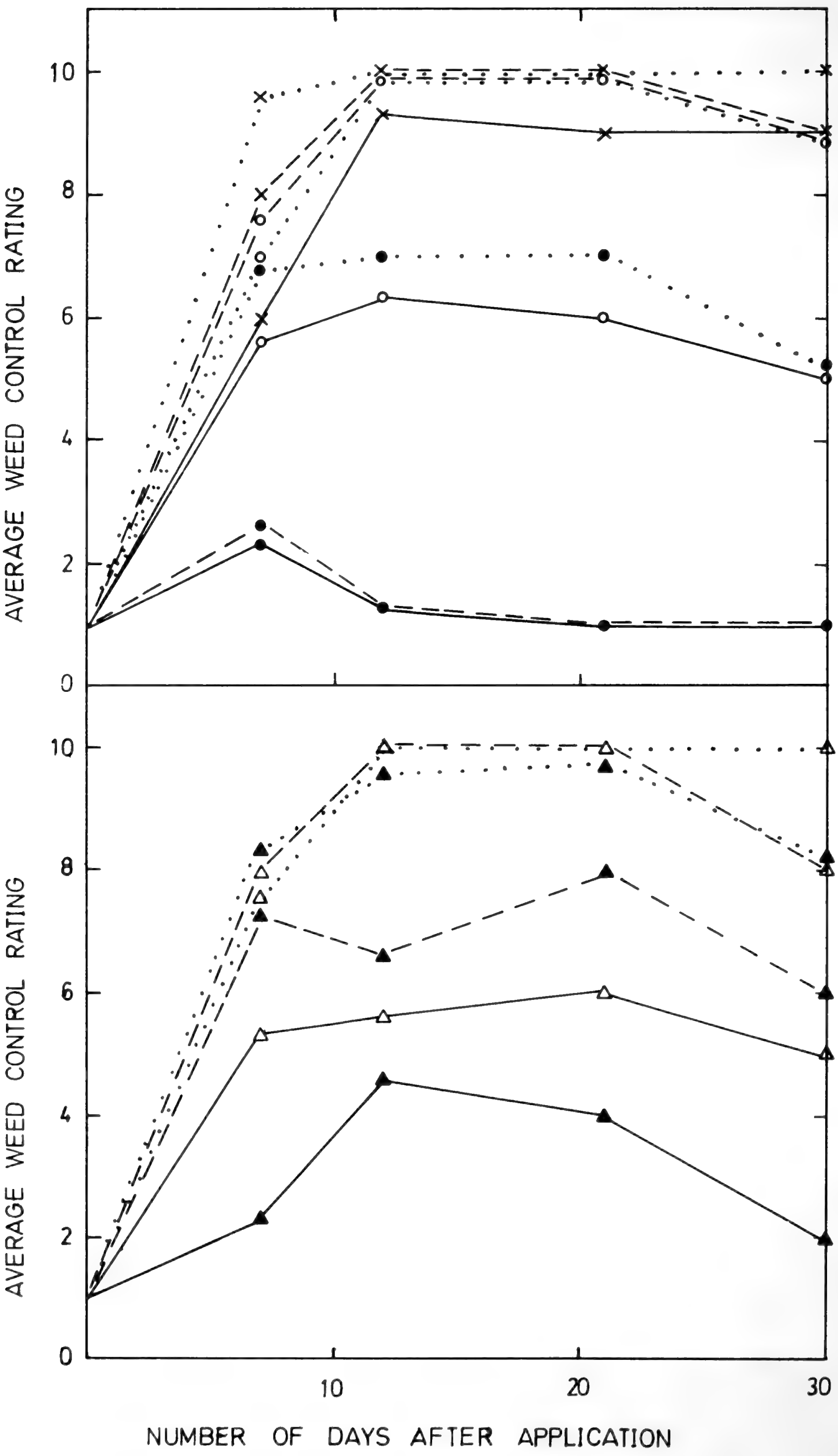

Fig. 3. Effects of herbicides on *Euphorbia thymifolia*.
The explanation for this figure follows that in Fig. 2.

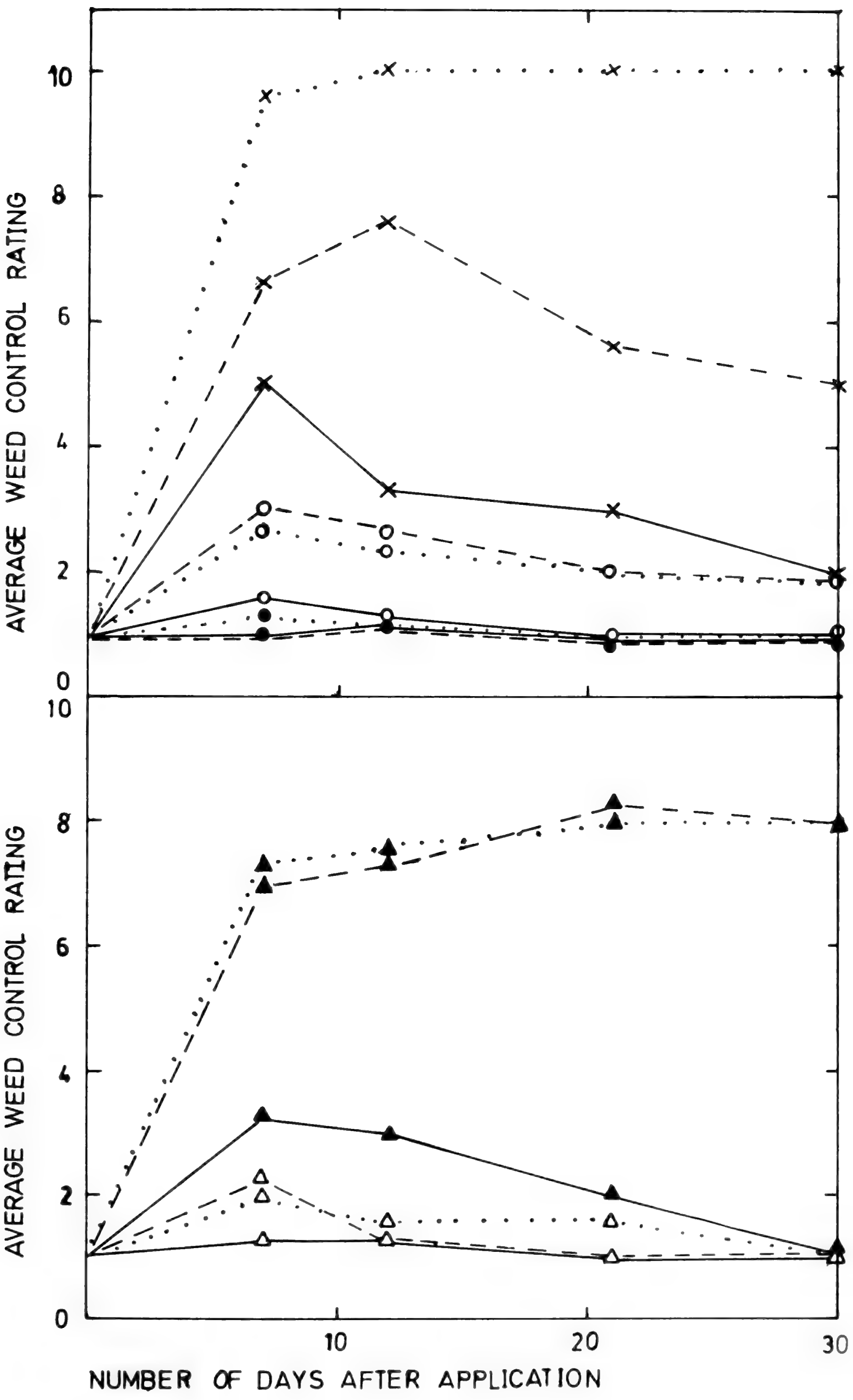

Fig. 4. Effects of herbicides on *Axonopus compressus*.
The explanation for this figure follows that in Fig. 2.

Table 2 summarises herbicide concentrations that affect weeds by at least a minimum control rating of '7'.

For the sake of convenience, it would be useful to have a herbicide which will control all three weeds (*A. compressus, E. thymifolia, C. kyllingia*) at the same time. Using the rating of '7' as the criterion, it is seen that herbicides like dicamba and 2,4-D could only control *E. thymifolia* but not the other two weeds. Similarly, bentazon at its highest concentration tested controlled *C. kyllingia* and *E. thymifolia* but not *A. compressus.* Dicamba, 2,4-D and bentazon were each not versatile enough for the purpose of providing control of all three weeds. Only applications of metribuzin at 0.6 or 1.2 g/l, or MSMA at 6.0 or 10.0 ml/l could be expected to control all three weeds at the same time. Results in Fig. 1 however show that metribuzin at 0.6 and 1.2 g/l, and MSMA at 10 ml/l caused excessive burn in Tifgreen Bermuda grass. This left only MSMA at 6 ml/l as the potential for use in universal control of all three weeds.

MSMA (6 ml/l) was sprayed on 3 m × 1 m plots at the rate of 55 ml spray solution per square metre using CP15 Knapsack sprayers. Plots were either sprayed only once at the start of the experiment or once a week for 3 weeks in succession. Since metribuzin at 0.6 g/l could control all three weeds but was too phytotoxic for Tifgreen Bermuda grass, it was decided to test metribuzin at 0.2 g/l to determine if repeated spraying could bring about the same effects as found for the higher concentration. Results show that repeated weekly spraying of MSMA for 3 weeks resulted in selective control of *A. compressus, C. kyllingia* and another weed *Brachiara distachya*;

Table 2
Herbicide concentrations that effectively controlled *C. kyllingia, E. thymifolia* and *A. compressus.*

| Herbicide | | *Cyperus kyllingia* | *Euphorbia thymifolia* | *Axonopus compressus* |
|---|---|---|---|---|
| Metribuzin | 0.2 | | x | |
| (Sencor WP 70) | 0.6 | x | x | x |
| g/l | 1.2 | x | x | x |
| Dicamba | 1.0 | | | |
| (Fez PE 400) | 2.0 | | x | |
| ml/l | 3.0 | | x | |
| Bentazon | 2.0 | | | |
| (Basagran 39.6%) | 6.0 | | | |
| ml/l | 10.0 | x | x | |
| 2,4-D | 2.0 | | | |
| (2,4-D amine 720) | 4.0 | | x | |
| ml/l | 8.0 | | x | |
| MSMA | 2.0 | | | |
| (MSMA 500) | 6.0 | x | x | x |
| ml/l | 10.0 | x | x | x |

Concentrations of herbicides that controlled the 3 weeds by at least a control rating of '7' are marked (X); these are considered effective for control of the respective weeds. Results shown here were extracted from Figs. 2–4.

*E. thymifolia* were weak in growth, ceased spreading but were not totally killed. *Cyperus radians*, a coarse, tufted sedge with wiry leaves and inflorescence stalks (Wong 1986) was affected by MSMA to the extent that tips of leaves and inflorescences were burnt but the tuft remained alive; growth was impeded although total killing of the weed did not occur. Metribuzin when sprayed at 0.2 g/l weekly for 2 weeks in succession resulted in total control of *E. thymifolia* but had no effect on *A. compressus*, *B. distachya* or *C. kyllingia* even after 3 applications (weekly) in succession. To confirm the selectiveness of MSMA at 6 ml/l, it was sprayed repeatedly at weekly intervals for 5 weeks on a 9 m × 2 m plot (55 ml spray solution per square metre). *A. compressus*, *C. kyllingia*, *B. distachya* were all controlled while the Tifgreen Bermuda grass began to grow, spreading itself to cover areas formerly covered with weeds. The entire plot looked darker green than the surrounding areas (Plate 1) by virtue of the cover eventually provided by Tifgreen Bermuda grass within the plot; surrounding areas were lighter green because they were still infested with weeds that gave the lawn a lighter green color.

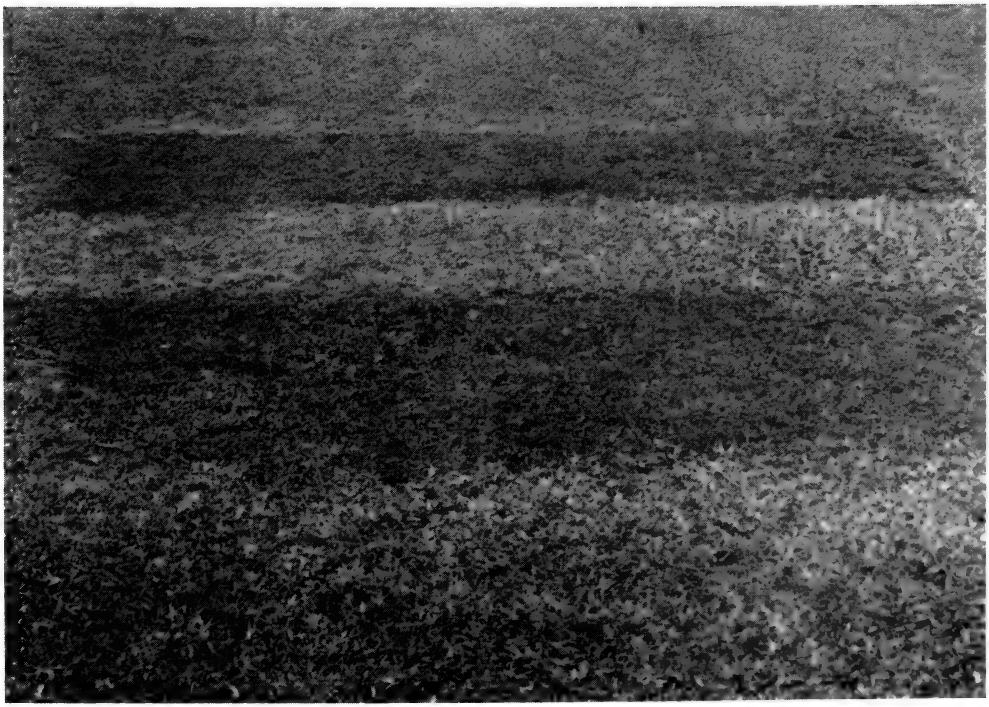

Plate 1. Weed control and the accompanying growth of Tifgreen Bermuda grass in MSMA-treated plots. The darker green plot of turf in the figure resulted from the eradication of weeds like *C. kyllingia*, *A. compressus* and *B. distachya* accompanied by active growth of Bermuda grass which was not affected by the herbicide and was also darker green in colour than the weeds. MSMA 500 (6 ml/l) was sprayed at weekly intervals for 5 weeks in succession.

## Conclusion

Chemical control of weeds by selective herbicides is possible. Care must however be taken to ensure the application of correct dosages. MSMA, a pentavalent arsenical herbicide considered to be of a low order of toxicity to man and animals, and which is inactivated upon contact with soil (Anderson 1977), was found to be highly selective in this trial. It controlled *A. compressus, B. distachya, C. kyllingia* and to a lesser extent *E. thymifolia* without damaging Tifgreen Bermuda grass. Metribuzin, an asymmetrical-triazine herbicide which is detoxified by microbial action in the soil (Anderson 1977), was more effective on *E. thymifolia.*

## Acknowledgements

I wish to thank Mr Rehan bin Yusoff and Mr Ang Peter for their technical assistance.

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# Annotated List of Seed Plants in Singapore (XI)*

HSUAN KENG
*c/o Department of Botany, National University of Singapore*

*Index to Families*

## II. Angiospermae-Monocotyledons

### 143. ALISMATACEAE

*Sagittaria sagittifolia* L.

Aquatic herb; to 50 cm tall; leaves basal, with petiolate sheath and arrow-shaped blade (15–30 cm long); flowers white, in panicles. Underground tubers globose, 4–5.5 cm across, edible; mostly imported from S. China especially during the Chinese New Year Season, sometimes cultivated as an ornamental. Vern. Ubi Keladi, Chinese arrowhead, 慈姑 .

### 144. BUTOMACEAE

*Limnocharis flava* (L.) Buch.

Aquatic herb, 50–70 cm tall; leaves petiolate, the blade ovate or suborbiculate, 6–28 cm long; flowers yellow, 2–8 or more in a stalked umbel. Native to S. America, sometimes spreading along ditches or in pools.

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*Continued from *Gard. Bull. Sing.* 39 (1): 67–95. 1986.

The author is indebted to Dr. Richard T. Corlett for going through the manuscript and for his suggestions.

## 145. HYDROCHARITACEAE

### *Key to the genera*

A. Fresh water plants
  B. Leaves spirally arranged or radical ........ *Blyxa*
  B. Leaves in whorls of 3–8 ........ *Hydrilla*
A. Marine plants
    C. Plants very delicate; leaves opposite, in spaced pairs on slender stems, ovate to lanceolate ........ *Halophila*
    C. Plants coarse; leaves arranged in 2 rows, ribbon-like
      D. Rhizome covered with soft black fibres; leaves 30–150 cm long ........ *Enhalus*
      D. Rhizome nearly naked; leaves 10–30 cm long ........ *Thalassia*

**Blyxa auberti** Rich.

Formerly called *Blyxa malayana* Ridl. Freshwater plant, leaves radical, narrow (less than 1 cm broad), 10–50 cm long; flowers bisexual, small, on a long stalk surrounded by a tubular spathe. In ponds and ditches, Nee Soon, Serangoon Road (*Ridley 8413*).

**Blyxa alternifolia** (Miq.) Hartog

Formerly called *Enhydrias angustipetala* Ridl. Leaves linear, 2–5 cm long, arranged along the stems. In muddy ponds and ditches, Chua Chu Kang, (*Ridley s. n.* in 1905).

**Enhalus acrocoides** Royle

Formerly called *Enhalus koenigii* Rich. Marine plant; rhizome thick, covered with stiff black fibres; leaves 2–3, strap-shaped, 0.5–1 m long; flowers small, unisexual, dioecious, the female in coiled, long-stalked inflorescence. In shallow sea water, Bajau (*Goodenough 3952*), Teluk Paku, Pulau Senang, Tanah Merah Besar, Changi.

**Halophila minor** (Zoll.) Hartog

Small marine plant; stem slender, lateral shoots short, usually with one pair of petiolate leaves; leaf-blades oblong-ovate, 0.7–1.4 cm long, with 3–8 pairs of side veins; flowers small, dioecious, solitary, axillary. Below tidal level on muddy bottom, Ponggol, (*Holttum s.n.* in 1924), Pasir Laba, Sentosa, Pulau Pawai, Labrador.

**Hal. ovalis** (R. Br.) Hook. f.

Like the above, but the leaf-blades ovate, larger (1–4 cm long), with more pairs (12–25 pairs) of side veins. Changi (*Ridley s.n.* in 1890), Woodlands, Pulau Senang.

**Hal. spinulosa** (R. Br.) Aschers.

Lateral shoots with 10–20 pairs of sessile distichous leaves; leaf-blades spathulate-oblong, serrulate, 1–2.3 cm long. Pulau Tekong (*Henderson & Corner, s.n.* June 16, 1929), Beting Kusa, Tanah Merah Besar.

**Hydrilla verticillata** (Roxb.) Royle

Fresh water plant; stems slender, much branched; internodes 0.3–5 cm long; leaves sessile, in whorls of 3–8, linear, 0.8–4 cm long, green with brown spots; flowers very small, unisexual. In ditches and pools, Tanjong Pasir Laba Road (*Sinclair 10836*).

**Thalassia hemprichii** (Ehrenb.) Aschers.

Marine plant; rhizome creeping, conspicuously noded; leaves 2–6, in 2 ranks; blades strap-shaped, 10–40 cm long; flowers dioecious, in few-flowered terminal inflorescence. In mud at low tide, Pulau Samulun (*Sinclair SFN 38581*).

## 146. NAJADACEAE

**Najas graminea** Delile
Fresh water submerged herb; stems slender, branched; leaves opposite or nearly so, linear lanceolate, 1.5–2.5 cm long, with 3 or more minute teeth on each side; flowers very small, green, unisexual. In ditches and ponds, Gardens' Lake (*Ridley 8946*, Type of *N. graminea* var. *angustifolia* Rendle).

**Najas Kingii** Rendle
Like the above, but leaves larger (2–4 cm long) and with more (6–19) teeth on each side. In streams, Tanglin (*Ridley s.n.* in 1889).

## 147. ZANNICHELLIACEAE

### *Key to the genera*

A. Leaves 7–13 nerved; style 2-fid; anthers inserted at the same level .................. *Cymodocea*
A. Leaves with a main vein and 2 thin marginal veins; style entire; anthers inserted at different levels ........................ *Halodule*

**Cymodocea rotundata** Aschers. & Schweinf.
Marine herb, submerged; stems distant, erect, with few leaves at the top, in 2 series; leaves linear or filiform, with a rounded top, 7–15 cm long and 7–13 nerved. Telok Paku, (*Sinclair SFN 40527*).

**Cym. isoetifolia** Aschers.
Tanah Merah Besar (*Sinclair SFN 39509*). In sandy, muddy, substratum near low water.

**Cym. serrulata** Aschers. & Magnus
Tanah Merah Besar (*Sinclair SFN 39508*).

**Halodule tridentata** (Steinh.) F.v.M.
Also called *Diplanthera uninervis* Aschers. Submerged marine herb; stems distant, erect, with few leaves at the top, in 2 series; leaves linear, 7–10 cm long, 3-toothed, the median tooth as long as or slightly longer than the lateral teeth; flowers solitary, unisexual, naked. In sandy coast, Pulau Senang (*Burkill 547*), Pulau Pawai.

## 148. TRIURIDACEAE

**Sciaphila maculata** Miers.
Slender saprophytic herb, 10–15 cm tall, purplish grey, usually not branched; leaves minute; flowers unisexual; perianth 6-lobed; stamens 6 in a staminate flower, and carpels numerous in a carpellate flower. In dense forests, living in decaying vegetable matter, very rare, Selitar (*Ridley s.n.* in 1880s). Formerly called *S. affinis* Becc.

## 149. LILIACEAE

### *Key to the genera*

A. Leaves thick and succulent, often spiny-edged ........................ *Aloë*
A. Leaves thin and flexible
  B. Leaves ovate or ovate-lanceolate
    C. Leaves, especially the upper ones, always with a long tendril-bearing tip; slender stemmed climber with underground tuber ........................ *Gloriosa*
    C. Leaves long-petiolated, erect; underground stem very short .................. *Peliosanthes*

B. Leaves long and narrow or sometimes scale-like
  D. Leaves scale-like, the function replaced by needle-like cladophylls; drooping or climbing ........ *Asparagus*
  D. Leaves long and narrow, grass-like; erect
    E. Stems leafy, in two rows ........ *Dianella*
    E. Leaves tufted, foliage plants
      F. Plants with prominent runners ........ *Chlorophytum*
      F. Plants crowded, with short and thick rhizomes ........ *Liriope*

*Aloë barbadensis* Mill.

Also called *A. vera* (L.) Webb. A short-stemmed, succulent plant; leaves pale green, sword-shaped, 30–60 cm long, crowded along the top of the stem, with marginal, dark-coloured spines; flowers yellow, orange or red, in lax panicles. Native of Cape Verde and Canary Island. This is the true aloe, a well-known medicinal plant; several other species and cultivated varieties are also introduced. 蘆薈

*Asparagus plumosus* Baker

Slender herbaceous climber, up to 1–2 m long; true leaves minute, dry, scale-like, replaced by fine, green, needle-like flattened branches (or cladophylls), 0.3–1 cm long; flowers small, axillary, solitary or in pairs, greenish or white. Native to S. Africa, often cultivated as an ornamental.

*Asp. sprengeri* Regel

Roots tuberous; stems climbing or drooping; flattened branches (or cladophylls) 1–2.5 cm long; flowers white, in short racemes. Native to S. Africa, sometimes planted. The tender shoots of another species, the garden asparagus (*Asp. officinalis* L.), a native of the Mediterranean, are sold in markets as vegetables.

*Chlorophytum comosum* (Thunb.) Baker

Herb; leaves radical, sessile, linear, 15–35 cm long, sometimes with white or pale yellow margins or median band; flowers white, in branched racemes. Native to S. Africa, often cultivated for its foliage, sometimes hanging from pendulous runners. 吊蘭

**Dianella ensifolia** (L.) DC.

Rhizomatous tufted herb, 60 cm to 1 m tall; leaves grass-like, in 2 rows, 20–60 cm long, sheathed below; flowers bluish or white, in a terminal panicle; filaments thickened; berry globose, deep blue, 0.7–1 cm across. In open or slightly shady places, often near the sea, Sungei Buloh (*Ridley s.n.* in 1891).

*Gloriosa superba* L.

Climbing plant with underground tubers; stems slender; leaves spirally arranged, narrowly lanceolate, sessile, 8–25 cm long, with a long-tapering tip, the tip of higher leaves forming a short, coiled tendril; flowers solitary, long-stalked, placed beside the leaves; perianth lobes at first pale yellowish green, than partly red with yellow margins, finally dark red, strongly bent backwards. Native to tropical Africa and Asia (but not wild in Malaya and Singapore), cultivated as an ornamental. All parts, especially the tubers, are poisonous to eat.

*Liriope spicata* Lour.

Herb, with semi-transparent rhizomes; leaves grass-like, linear-lanceolate, tufted, 25–50 cm long, 1–1.8 cm wide, often with white margins; flowers small, pale lilac or white, in short spikes 10–15 cm long (pot-plants usually producing shorter leaves and inflorescences). Native to S. China and Japan, commonly cultivated as a pot plant; the rhizomes are of medicinal value, 麥門冬. Another broader-leaved (1–2.5 cm wide) species, *L. muscari* Bailey, with violet flowers, is less commonly cultivated.

**Peliosanthes teta** Andr. ssp. **humilis** (Andr.) Jessp.
Herb; leaves crowded on a horizontal rhizome, erect, ovate-lanceloate, 15–20 cm long, 5–6 cm wide; with strong longitudinal veins; petioles 12–15 cm long; flowers globose, violet or purple, in racemes about 10 cm long. Bukit Timah, Reservoir woods. (*Ridley s.n.* 1908), Selitar. Formerly called *P. violacea* Wall, and *P. viridis* Ridl.

## 150. AGAVACEAE

### *Key to the genera*

A. Ovary superior
  B. Perianth-segments free ........ *Yucca*
  B. Periath-segments united at the base
    C. Ovules 4-many per ovary-locule ........ *Cordyline*
    C. Ovule solitary
      D. Shrubs or trees; stems present, woody ........ *Dracaena* (incl. *Pleomele*)
      D. Herbs; stems very short, fibrous ........ *Sansevieria*
A. Ovary inferior
      E. Flowers regular; inflorescence paniculate ........ *Agave*
      E. Flowers zygomorphic; inflorescence racemose ........ *Polianthes*

*Agave americana* L.
A large, stemless plant with a rosette of 50–60 thick, sword-shaped leaves; the blades 0.8–1.5 m long, the marginal spines often recurved; flowers pale yellow, in large panicles on a culm of 4–8 m tall. Vern. Century plant 龍舌蘭. A native of Mexico, sometimes planted. Several other species (e.g. *A. sisalana* Perr., *A. germinoflora* Ker-Gawl.) are also occasionally planted.

*Cordyline terminalis* (L.) Kunth
Shrubby, 3–4 m tall; stems slender; leaves narrowly oblong, 30–50 cm long, arranged in close spirals at the tip of branches; petioles 5–15 cm long; flowers lilac, in terminal panicles. Native of temperate Asia and Australia and the Pacific Islands, planted in gardens. The leaves are in a wide range of colours. 朱蕉. Several other Australian species, e.g. *C. stricta* Endl., *C. fruticosa* A. Chev., are also occasionally cultivated.

**Dracaena aurantiaca** Wall.
Shrub, 2–3 m tall; little or not branched; leaves varying from lanceolate to ovate, 0.3–1 m long, green or purple with circular lighter patches, crowded on the ends of branches; petioles winged; flowers greenish white or purple, in terminal panicles, 0.5 m long. In forests, Bukit Timah, Kranji, Changi, Selitar (*Ridley 1650*).

**Drac. brachystachys** Hook. f.
Little branched shrub, 5–6 m tall; leaves crowded at the ends of branches; leaves sword-shaped, acuminate, to 1 m long. Pulau Serapu (*Ridley 10128*).

**Drac. elliptica** Thunb.
Slender shrub, 1–2 m tall; branches drooping; leaves lanceolate or broadly oblong, 12–15 cm long. Gardens' Jungle (*Ridley 4412*), Chua Chu Kang.

*Drac. fragrans* Ker. (= *Pleomele fragrans* N. E. Br.).
Tall shrub, to 6–8 m high; leaves oblong-lanceolate, 0.5–1 m long, 5–10 cm wide, green or with light longitudinal bands, crowded on the ends of branches, without a petiole; flowers yellowish, clustered on branches of a panicle, fragrant especially at night. Native of tropical Africa, sometimes planted. Several other African species

are also commonly planted, these include: *D. godseffiana* Sand. (leaves oblong-ovate, green marked with light dots) *D. sanderiana* Sand, ex Masters (leaves long-lanceolate, white-margined), etc.

**Drac. granulata** Hook. f.

Tall tree, 15–20 m high, branched above; branches densely leafy; leaves linear, acuminate, 15–25 cm long. In forests, Bukit Timah, Bukit Mandai (*Ridley 3800*).

**Drac. maingayi** Hook. f.

Large tree, 15–20 m tall, with many branches forming a dense crown; leaves oblong-lanceolate, acuminate, 25–30 cm long. Common in sandy and rocky woods near the sea, Changi (*Ridley 4413*), Bukit Timah, Labrador.

**Drac. porteri** Bak.

Low, little branched shrub, 1–1.5 m tall; leaves linear or linear lanceolate, 30–40 cm long. In lowland woods, Singapore (*Wallich 5148B*), Gardens' Jungle.

**Drac. singapurensis** Ridl.

Shrub with slender stems, less than 40 cm tall; leaves lanceolate or elliptic, acute, 15–18 cm long. Bukit Timah, Chua Chu Kang (*Ridley 6235*).

**Drac. umbratica** Ridl.

Erroneously called *D. terniflora* Roxb. in earlier literature. Low shrub, little branched, to 1 m high; leaves lanceolate to elliptic, 3–5 cm long. Gardens' Jungle, Changi (*Ridley 4758*).

*Polianthes tuberosa* L.

Herb, 1 m tall, tuberous beneath; basal leaves narrow, red-spotted on the under surface, 15–50 cm long; upper leaves gradually shorter and then passing into bracts; flowers white, fragrant, in pairs on terminal spikes. Native to Mexico, sometimes cultivated. 晚香玉 .

*Sansevieria trifasciata* Prian

Herb, leaves 2–6 arising from the underground rhizome, the blades erect, sword-shaped, leathery, cross-banded dark and light green, 0.3–1 m long; flowers greenish white or greyish, in fascicles on a raceme 40–75 cm long. Native to tropical Africa, sometimes cultivated. Vern. Bowstring hemp, 虎尾蘭 . Another introduced species is *S. cylindrica* Bojer which has erect cylindric leaves 0.5–1 m long. Their strong fibres are made into mats, bowstrings, etc.

*Yucca aloifolia* L.

Stems simple or branched, 1–3 m tall; leaves sword-shaped, 20–50 cm long, hard and spiny; flowers white, in panicles of 30–60 cm long. Native to the West Indies and eastern N. America. A form with white-streaked leaves is cultivated. Another species with smooth leaf-margins, *Y. gloriosa* L. is also introduced.

## 151. SMILACACEAE

### *Key to the genera*

A. Perianth-segments free; stamens 6, free .................................................. *Smilax*
A. Perianth-segments united; stamens 3, fused ....................................... *Heterosmilax*

**Heterosmilax indica** A. DC.

Climber, with stipular-tendrils; stems slender, unarmed; leaves ovate-lanceolate, with a round base, 10–20 cm long, 3–8 cm wide; flowers in umbels. Once collected from Tanjong Katong (*Hullett s.n.*), now extinct.

**Smilax bracteata** Presl var. **barbata** (Wall. ex DC) Koyama
Woody climber, climbing by stipular-tendrils; stems stout, covered with red and whitish bristles and conic prickles; leaves thick leathery, ovate, with a round base, 15–20 cm long, 7–15 cm wide, glaucous beneath; petioles thick, 3–4 cm long; flowers unisexual, in compound umbels. In open country and forest edges, Tanglin, Bukit Timah (*Ridley 4811, 8043*).

**Smil. calophylla** Wall. ex DC
Wiry shrub, erect, unarmed; leaves lanceolate, acuminate, 3-nerved, glaucous beneath, 10–15 cm long; flowers yellow, unisexual, in small, sessile umbels; fruit globose, reddish brown. In forests, Bukit Timah, Jurong, Chua Chu Kang (*Ridley s.n.* in 1892).

**Smil. leucophylla** Bl.
Woody climber, stout, sparsely prickly; leaves leathery, ovate-oblong, acuminate, 3-nerved, 15–25 cm long; petioles 1–1.5 cm long, with a large dilated sheath. In forests, Bukit Timah, Tanglin, Bukit Mandai (*Ridley 10403*). Vern. Ubi danan.

**Smil. megacarpa** DC.
Stout woody climber, prickly, with strong stipular-tendrils; leaves leathery, dark green, oblong to elliptic, 3-nerved, 8–20 cm long; petioles 1.5–4 cm long; thick, twisted, sheathed below; fruit globose, 1.5 cm across, yellow or dark purple. In woods, Tanglin (*Ridley 4815, 5106*), Bukit Mandai.

**Smil. myosotiflora** DC.
A slender climber; leaves herbaceous, lanceolate or ovate-oblong, caudate, 3-nerved, 10–15 cm long. In forests, Gardens' Jungle (*Ridley 6250*). Sinclair recorded another species, *S. woodii* Merr. without certainty as occuring in Singapore based on *Sinclair SFN 38570* collected from Jurong Road in 1949.

## 152. AMARYLLIDACEAE

### *Key to the genera*

A. Ovary superior .................... *Allium*
A. Ovary inferior
  B. Flowers solitary, erect .................... *Zephyranthes*
  B. Flowers in umbels or globose-heads, erect or pendulous
    C. Flowers without a crown or cup
      D. Flower-stem hollow (leaves long and narrow; flowers large, trumpet-shaped) .................... *Hippeastrum*
      D. Flower-stem solid
        E. Flowers 50–100 in a globose head; leaves oblong, petiolate .................... *Haemanthus*
        E. Flowers 6–12 in a congested umbel; leaves long and narrow, without a petiole .................... *Crinum*
    C. Flowers with a crown or cup inside the perianth-tube, consisting of joined filaments of stamens
      F. Leaves board, narrowed to a petiole
        G. Flower-segments spreading, fragrant .................... *Eucharis*
        G. Flower-segments ascending, odourless .................... *Eurycles*
      F. Leaves sword-shaped, without a petiole .................... *Hymenocallis*

*Allium fistulosum* L.
Bulbous herb; leaves radical, long-tubular, hollow, 30–50 cm long; flowers whitish, small, in dense, terminal umbellate-heads; flowering stem 40–60 cm long. Native of temperate Asia, cultivated for the edible leaves. Vern. Spring onion, Welsh onion, 大葱 . Several other species are used as vegetables or for cooking, these

include *A. cepa* L. (the onion, 洋葱 ), *A. sativum* L. (the garlic, 蒜 ), *A. tuberosum* Rottl. ex Spreng. (or as *A. ramosum* L., the Chinese leek, 韮菜 ), etc.

**Crinum asiaticum** L.

Bulbous herb; leaves narrowly lanceolate, acuminate, 0.5–1.5 m long; flowering stem 1–1.2 m, with 6 or more flowers on a congested umbel; flowers white, 12–18 cm long, the segments narrow; filaments reddish; fruit irregularly globose, 4–5 cm across, with one or few large green seeds inside. On sandy shores, Changi, Sungei Buluh, Sungei Tengah (*Ridley s.n.* in 1891), Kranji; sometimes also cultivated. Vern. Bakung, 文殊蘭 .

*Crinum giganteum* Andr.

Flowers larger (about 25 cm long) and with broader segments than the above species. Introduced from Java, thus called 'Java Lily'.

*Eucharis grandiflora* Planch. & Link

Bulbous herb, with 2–4 leaves; leaf-blades oblong or ovate, 20–25 cm long; petioles as long as the blades; flower stems 50–80 cm long, with 2–5 flowers at the tip; flowers white, 6–8 cm across, widened part of the perianth-tube pale yellow inside. Native of Colombia (''Amazon Lily''), sometimes cultivated. 白鶴花.

*Eurycles amboinensis* Loud.

Bulbous herb; leaves broadly heart-shaped, 20–30 cm long; petioles stout, 15–40 cm long; flowering stem 10–50 cm long. Native of N. Malaya, the Philippines to E. Australia, occasionally cultivated. Also called *E. sylvestris* Salisb.

*Haemanthus multiflorus* Martyn

Bulbous herb; leaves 4–7, oblong, with a stout midrib, 20–30 cm long; scape solid, flattened; flowers bright or pale red, numerous in a globose head 12–16 cm across (''Blood Lily'' or ''Powder puff''). Native to tropical Africa, sometimes cultivated. 孤挺花 .

*Hippeastrum puniceum* Urb.

Bulbous herb; leaves 6–8, strap-shaped, 30–45 cm long, usually not fully grown before flowering; flowering stem 30–50 cm long, with 2–4 or more flowers at the top; flowers trumpet-shaped, 9–12 cm long, red, orange-red or in other colours. Native to tropical America (''Barbados Lily''), sometimes cultivated; also called *H. equestre* Herb. 火球花 .

*Hymenocallis littoralis* Salisb.

Bulbous herb; leaves radical, strap-shaped, acute, with a narrow base, 40–70 cm long; scape flattened, 2-edged, 30–70 cm long; staminal cup (or crown) 2.5–3 cm long. Native to tropical America, sometimes cultivated (''Spider Lily''). Also called *Pancratium littorale* Jacq.

*Zephyranthes candida* Herb.

Bulbous herb; leaves linear, 12–40 cm long, very thick; scapes with only one flower at the tip; flower white, sometimes rose-tinted outside, 4–5 cm long. Native to S. America. 葱蘭. Several other species are also occasionally cultivated, these include: the light-pink flowered *Z. carinata* Herb, the yellow-flowered *Z. carinata* Herb, the yellow-flowered *Z. flava* Bak. and others.

## 153. HYPOXIDACEAE

**Curculigo orchioides** Gaertn.

Rhizomatous herb; leaves narrowly lanceolate, 1–1.2 m long including the petiole, 12–15 cm wide, glabrous; flowers bisexual, several to many in erect, head-like inflorescence on a short scape (about 10 cm long); bracts lanceolate, 2–3.5 cm long; perianth 1–1.2 cm across, pale outside and bright yellow inside. In sunny or slightly shady places, formerly all over the island. Cluny Road (*Ridley s.n.* in 1895), Bukit Timah, Chua Chu Kang. Called *C. latifolia* Dryand ex W. T. Ait in literature.

**Curc. recurvata** Dryand. ex W. T. Ait
Differs from the above species in the nodding head-like inflorescences. (also called *Molineria recurvata* Herb. by some authors). Gardens (*Ridley s.n.* in 1896).

**Curc. villosa** Wall.
Like *C. orchioides*, but the undersurface of leaves and petioles are densely hairy, and bracts are stiff, oblong, 4–5 cm long. Chua Chu Kang (*Ridley s.n.* in 1895), Bukit Timah.

## 154. TACCACEAE

**Tacca integrifolia** Ker-Gawl.
Rhizomatous herb; leaves simple, entire, lanceolate, 0.8–1 m long including the petiole; flowers in umbels; involucral bracts leafy, dark purple; scape 45–60 cm long, stout; floral bracts thread-like, 12–15 cm long; perianth 1.5–2 cm across, purple; segments in 2 series, the outer ones thinner, paler and smaller than the inner ones. In forests, Bukit Timah. Chua Chu Kang, (*Ridley s.n.* in 1894). Formerly called *T. cristata* Jack.

**Tacca leontopetaloides** (L.) O. K.
Leaves tripartite or pinnatifid, 0.5–1 m long; flowers green. On sandy shores, Pulau Semakau, *Sinclair SFN 38925*; Pulau Senang.

## 155. DIOSCOREACEAE

*Dioscorea alata* L.
Stem slender, 4-angled or -winged, twining in anti-clockwise direction; leaves opposite, orbiculate-cordate, 5–7-nerved. Native of E. Asia, cultivated for its underground tubers ("the greater Yam"). 大薯 .

**Dios. bulbifera** L.
Stem twining clockwise, glabrous, often with axillary bulbils; leaves cordate, broadly ovate, 8–40 cm long; 6–30 cm wide, conspicuously cross-veined; petiole 2–13 cm long; flowers seesile or nearly so, white to dark violet; male spikes 2–3.5 cm long, in panicles; female spikes in axillary fascicles, 10–20 cm long. In waste ground and near villages, Tanglin, Changi, Pulau Merambong (*Corner 29960*).

*Dios. esculenta* (Lour.) Burk.
Stem twining clockwise; leaves alternate; tubers 4 to many, close to the soil surface, anchored by strong thorny roots. Native to Indo-China, cultivated for its edible tubers ("the lesser yam"). 刺薯 .

**Dios. glabra** Roxb.
Stem rather stout, thorny at base; leaves lanceolate to elliptic-ovate, 4–10 cm long, glabrous; petiole 2–2.5 cm long; male and female spikes 10–30 cm long, in panicles. Common in forest, Gardens' Jungle, Tanglin, Bukit Mandai.

**Dios, hispida** Denns.
Stem spiny, twining closewise; leaves 15–30 cm long, palmately 3-foliolate; Male panicles 30–50 cm long. Several cultivated varieties; tubers mostly globose, usually not lobed. Bukit Timah (*Goodenough s.n.* in 1914).

**Dios. laurifolia** Wall.

Stem slender, smooth or prickly; leaves lanceolate to oblong, 3-nerved, 5–8 cm long; male and female spikes in panicles. In edges of forests, Tanglin, Gardens' Jungle (*Ridley s.n.* in 1893), Bukit Timah, Changi.

**Dios. polyclades** Hook. f.

Stem stout, pubescent, thorny near the base; leaves ovate, hairy, 5–7 cm long; petiole as long as the blade, hairy; male and female spikes in panicles. In forest edges, Chua Chu Kang, Sungei Pandan, Bukit Timah.

**Dios. prainiana** R. Kunth

Stem slender, glabrous, unarmed; leaves alternate or opposite, membranous, elliptic-oblong, 5–7-nerved, 10–15 cm long; petiole 4–6 cm long; male spikes 30–60 cm long. In forests, Bukit Timah, Gardens' Jungle.

**Dios. pyrifolia** Kunth

Stem pubescent, the base thorny; leaves opposite, leathery, ovate, cordate, 5-nerved, 6–10 cm long, pubescent below; petiole 2–5 cm long; male spikes 30 cm or more long; female spikes 8–10 cm long. Common in thickets, Chua Chu Kang, Changi.

**Dios. stenomeriflora** Prain & Burk.

Large climber, to 25 m tall; stem purple; leaves leathery, glabrous, elliptic, cordate, 3-nerved, 10–25 cm long; male spikes solitary, axillary; flowers long tubular, about 1 cm long. In forest edges, Changi. Another large climber with large cordate-hastate leaves, *D. sansibarensis* Pax, a native of tropical Africa, was once planted in the Botanic Gardens; now escaped and more or less naturalized in the surrounding areas of the Gardens; propagated by bulbils.

## 156. PONTEDERIACEAE

### *Key to the genera*

A. Flowers zygomorphic; perianth forming a tube at the base; leaves with a short swollen petiole ........ *Eichhornia*
A. Flowers regular; perianth segments free; leaves with a long slender petiole .......... *Monochoria*

*Eichhornia crassipes* (Mart.) Solms.

Stoloniferous floating herb; roots dark brown, much branched; leaves nearly rounded, 5–20 cm long and broad; petiole spongy, 10–30 cm long, much swollen near the centre; flowers zygomorphic, lilac blue; segments 6, the median one larger, 3–3.5 cm long, with a yellow blotch near the centre. Native of Brazil, in aquaria and ponds; a serious pest in water catchment areas. Vern. Water hyacinth, 鳳眼蓮 .

**Monochoria hastata** (L.) Solms.

Aquatic herb; leaves spear-shaped, 6–10 cm long and wide, with 2 pointed lobes at the base; petiole 20–50 cm long, more or less erect; flowers light blue-violet, 2–2.5 cm across, in head-like inflorescence arising from the axil of a sheath in leaf-stalk. In ditches and wet places, Changi (*Goodenough s.n.* in 1890), Gelang.

**Monoch. vaginalis** (Burm. f.) Presl.

Leaves narrower than the above species, the base rounded or heart-shaped, not pointed. In ditches and ponds, Ang Mo Kio (*Ridley* 4598), Chua Chu Kang, Gelam. 鴨舌草 .

## 157. IRIDACEAE

*Trimezia martinicensis* Herb.

Bulbous herb; leaves grass-like, 50–60 cm long, in 2 rows; flowering scape 60–70 cm long with 6 or more flowers in succession; flowers bright yellow, the inner segments oblong, 2–2.5 cm long, with a dark brown blotch at the base inside. Native to Mexico, cultivated and more or less naturalized. (Several species of *Belamcanda, Moraea* etc. are occasionally planted in gardens.)

## 158. BURMANNIACEAE

### *Key to the genera*

A. Stamens 3
  B. Ovary 3-loculate; autotrophic or saprophytic .................................. *Burmannia*
  B. Ovary 1-loculate; saprophytic .............................................. *Gymnosiphon*
A. Stamens 6 ................................................................. *Thismia*

**Burmannia championii** Thw.

Saprophytic herb; stem swollen below and buried in decaying debris, slender above ground, whitish, 8–20 cm long; leaves scale-like; flowers 3 or more in small clusters, yellowish white; perianth tube 3-angled, not winged. In forests, Bukit Timah (*Ridley s.n.* in 1890), Changi. Formerly called *B. tuberosa* Becc.

**Burm. coelestis** D. Don.

Autotrophic herb; stem slender, 10–25 cm tall; leaves small, narrow, to 1.2 cm long, crowded at the base of stem; flowers 1–4 at the tip of stem, the perianth tube about 1 cm long, 3-winged, light blue, with 6 small yellow or white perianth segments. In open grassland or sandy places, locally common. Botanic Gardens, Changi, Kranji, Bedok (*Ridley s.n.* in 1903).

**Gymnosiphon aphyllus** Bl.

Saprophytic herb, 10–17 mm long; leaves acute, 1–2 mm long; flowers white or lilac, 5–6 mm long, in loose inflorescence. Formerly collected from Bukit Timah (*Ridley s.n.* in 1893), now probably extinct.

**Thismia aseroe** Becc.

Slender, saprophytic herb; stem erect from creeping rhizome; flowers solitary, on top of the erect branch; perianth-tube obconical, 1–1.2 cm long, the segments triangular, with bright orange, long tails. In dense forests, formerly collected at Woodlands, Bukit Timah (*Ahmad s.n.* in 1932), Kranji, now probably extinct.

**Thism. fumida** Ridl.

Like the above, but with narrower perianth-segments. Formerly collected from forests at Chua Chu Kang, now extinct.

## 159. PHILYDRACEAE

**Philydrum lanuginosum** Banks ex Gaertn.

Grass-like herb; leaves narrow linear, 30–40 cm long, 1–1.2 cm wide; flowering stem to 1 m tall, often branched at the top; flowers yellow, in compact heads, subtended by stiff brown bracts; perianth segments 6, the outer 3 very unequal, the inner three equal. In wet open places, formerly collected from Bedok (*Ridley 5907*), now extinct. 田葱 .

## 160. COMMELINACEAE

### *Key to the genera*

A. Cultivated plants
  B. Short-stemmed; leaves sword-shaped, dark green above, crowded in a rosette .......... *Rhoea*
  B. Stem slender, trailing; leaves oblong, alternate
    C. Outer and inner perianth-lobes free .......... *Tradescantia*
    C. Outer and inner perianth-lobes united below .......... *Zebrina*
A. Native plants (and weeds)
  D. Inflorescence a compact head, breaking out through the base of the leaf-sheath .......... *Forrestia*
  D. Inflorescence terminal or axillary, not breaking out through the base of leaf-sheath
    E. Inflorescences congested, enveloped by a spathe or overlapping bracts
      F. Inflorescences terminal; stamens 6 .......... *Cyanotis*
      F. Inflorescences terminal and axillary; stamens 3 .......... *Commelina*
    E. Inflorescences more or less branched, not enveloped by a spathe or overlapping bracts
      G. Fruit blue, smooth and shining, not dehiscent .......... *Pollia*
      G. Fruit whitish, dehiscent
        H. Inflorescence densely flowered; flowers hairy, 6 stamens all fertile .......... *Floscopa*
        H. Inflorescence fewer flowered, the branches slender; flowers not hairy, only 2 or 3 stamens are fertile .......... *Murdannia*

**Commelina attenuata** Koen.

Creeping herb, rooting at the nodes, with ascending, upright branches 20–30 cm high; leaves linear-lanceolate, recurved, 1.5–2 cm long; sheath hairy; flowers in cymes, enclosed in a green, folded, funnel-shaped spathe; peduncle 1 cm long; flowers bright blue, stamens 3. In sandy sea-shores, Changi (*Ridley 6003*), Gelang.

**Comm. benghalensis** L.

Like the above species, but leaves elliptic or ovate, hairy; the leaf-tip blunt. In waste places, Gelang (*Ridley 3856*), Tanglin.

**Comm. diffusa** Burm. f.

Also called *C. nudiflora* L. Like *C. attenuata*, but leaves ovate-lanceolate, glabrous. Common in waste ground, Changi (*Ridley 3935*).

**Cyanotis cristata** D. Don

Prostrate herb, up to 30 cm tall, hairy; leaves oblong-lanceolate, 1.5–2.5 cm long; sheathed below; inflorescence short, terminal, enclosed by overlapping bracts; flowers pale blue. In sandy places near the sea, Changi, Gelang (*Ridley s.n.* in 1893). Formerly called *C. barbata* D. Don.

**Floscopa scandens** Lour.

Slender creeping herb, ascending branches 15–30 cm high; leaves narrowly elliptic, pointed at both ends, 5–8 cm long, shortly petioled; panicle terminal, 3–5 cm long, with many ascending branches; flowers pink. In muddy ditches or damp places, Tanglin (*Daud 6007*).

**Forrestia gracilis** Ridl.

Stout herb, creeping shortly at base; erect stem slender, 1 m tall, glabrous; leaves lanceolate, 15–20 cm long, the margin red-hairy; petiole winged; flower-heads small, with few sessile, white flowers. In forests, Tanglin, Pulau Ubin (*Ridley 4810*), Bukit Timah. Another species, *F. marginata* Hassk., with stout but creeping stems, was recorded from Bukit Timah by Wallich. (Note: Correct name for the genus is *Amischotolyte*).

**Murdannia nudiflora** (L.) Brenan

Formerly called *Aneilema nudiflorum* Wall. Creeping herb; ascending branches slender, to 30 cm tall, leaves lanceolate, 2–8 cm long, the tip acute; sheath bearded; cymes terminal, 3–5 cm long, branched at the tip; flowers small, violet, perfect stamens 2. In waste ground and dry sandy places.

**Murd. vaginata** (L.) Brueckn.

Formerly called *Aneilema vaginatum* (L.) R. Br. Leaves linear, fleshy, 5–7 cm long. In sandy places, Telok Kurau, Besut (*Sinclair & Kiah S.F.N. 40785*).

**Pollia sorzogonesis** Endl.

Stem slender, hairy, erect, 1 m tall; leaves lanceolate, the tip acuminate, 15–20 cm long; panicle terminal, pubescent, 20–30 cm long and wide, the branches spreading; flowers small, white; perfect stamens 3. In forests, Pulau Ubin (*Ridley 4759*).

*Rhoeo spathacea* (Sw.) Stearn

Formerly called *R. discolor* Hance. Short-stemmed herb; leaves erect or ascending, sword-shaped, 15–25 cm long, green above and purplish beneath; flowers white, small, in axillary clusters, enveloped by 2 boat-shaped bracts (''Oyster plant''). Native of tropical America, cultivated as an ornamental. 紫萬年青 .

*Tradescantia fluminensis* Vell.

Ascending or creeping herb; leaves oblong, 4–8 cm long, green or white-striped above, purple beneath; flowers white, in clusters. Native of S. America, this and several other species are sometimes cultivated.

*Zebrina pendula* Schnizl.

The stem trailing along the ground, rooting at the joints; leaves oblong, 5–7.5 cm long, alternate, with silvery green and purple stripes in the middle and around the margin; reddish purple beneath. Native of Mexico, cultivated. 吊竹草 .

## 161. FLAGELLARIACEAE

### *Key to the genera*

A. Climbers; leaves lanceolate, the tip transformed into tendrils; flowers bisexual ........ *Flagellaria*
A. Large erect herbs; leaves normal; flowers unisexual ................................ *Hanguana*

**Flagellaria indica** L.

Climber; stem slender but strong, 3–10 m long; leaves linear-oblong, 8–25 cm long, usually ending in a short coiled tendril; flowers white, bisexual, in a widely branched terminal panicle, 8–50 cm long. In open thickets near the sea, Kranji, Bajau (*Ridley 3589a*), Changi. 鞭籐 .

**Hanguana malayana** (Jack) Merr.

Formerly called *Susum malayanum* (Jack) Hook. f. Large erect herb, aquatic or terrestrial, highly variable; leaves grass-like, tapering at both ends, 30–90 cm long, densely nerved, rather thick; flowers unisexual, in a terminal panicle, 40–50 cm long. In forests and in damp places, Bukit Timah, Seletar, Ponggol, Bukit Panjang (*Ridley s.n.* 1907).

## 162. XYRIDACEAE

**Xyris complanata** R. Br.

Formerly called *X. anceps* Lam. Tufted herb; leaves linear, stiff, grass-like reddish, 10–50 cm long; flower-head with many dark brown imbricate bracts, on a stiff, slender, often twisted scape, 15–60 cm long; flowers yellow. In open sandy places, Balestier Plain, Pulau Tekong, Changi, Geylang (*Ridley 5757*).

**Xyris pauciflora** Willd.

Like the above, but plants smaller and shorter (leaves 7–25 cm long) and the head with fewer flowers. Balestier Plain (*Ridley 5877*), Water Catchment Areas.

## 163. ERIOCAULACEAE

**Eriocaulon longifolium** Nees

Herb with fibrous roots; leaves linear, grass-like, 8–30 cm long; scapes slender, erect, 30–45 cm high, with a globose or ovoid, greyish head at the tip; flowers minute, unisexual. Common in open damp places and ditches, Tanglin, Water Catchment Areas, Jurong (*Ridley s.n.* in 1889). Formerly called *E. sexangulare* L.

**Eriocaulon truncatum** Buch. Ham. ex Mart.

Smaller than the above species; leaves 3–5 cm long; scapes 4–10 cm high. Along damp paths on sandy ground, Tanglin, Bukit Mandai (*Ridley 3920*), Water Catchment Areas.

## 164. BROMELIACEAE

*Ananas comosus* (L.) Merr.

Perennial herb; leaves thick, linear lanceolate, 50–120 cm long, with sharp marginal spines; flowers in a dense, leafy crowned head; scape stout, 0.5–1 m tall; many small juicy fruits forming a spurious, broadly ellipsoid fruit ("pine-apple" 鳳梨 ), 10–30 cm long. Native to tropical America, many cultivated varieties, some as ornamentals, mostly for the edible fruits. Several others of this family (also from trop. America) are occasionally cultivated as ornamentals. These include: *Aechmea bracteata* Griseb. (rosette-forming herb, with red, ribbon-like bracts on the branched inflorescence), *Pitcairnia integrifolia* Ker-Gawl. (leaves forming crowded rosettes; flowers scarlet, on a panicle arising from the leaf centre), and *Tillandsia usneoides* L. (a rootless plant, with slender greyish hanging stem and narrow, curved leaves 3–6 cm long, commonly known as "Spanish moss"), etc.

## 165. PALMAE

### *Synoptic key to the genera**

A. Leaves palmate or palmately divided ......... *Licuala*, *Livistona* (native and cult.), *Rhapis* (cult.)
A. Leaves pinnate or pinnately divided, (twice pinnate in *Caryota*)
  B. Leaf-divisions folded back in bud, trough-like ....................... *Arenga* (cult.) *Caryota*
  B. Leaf-divisons infolded in bud, roof-like
    C. Female inflorescence head-like, fruit cluster globose ............................. *Nypa*
    C. Inflorescences spike-like, often forming in panicles
      D. Fruit covered with scales; leaves usually spiny
        E. Erect palms .......................... *Metroxylon* (cult.), *Raphia* (cult.) *Salacca*

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* Only the native and commonly cultivated genera are treated.

E. Climbing rattans ......*Calamus, Daemonorops, Korthalsia, Myrialepis Plectocomis*
D. Fruit smooth; leaves usually not spiny
F. Mostly solitary palms ..............................................................*Archontophoenix, Areca, Cocos, Elaeis, Roystona* (all cultivated)
F. Palms forming clumps .................*Chrysalidocarpus* (cult.) *Cyrtostachys, Iguanura, Nenga, Oncosperma, Pinanga, Ptychoraphis, Ptychosperma* (cult.)

*Archontopheonix alexandrae* (F. Muell.) Wendle. & Drude
Stem solitary, straight and slender, to 12 m tall (and less than 25 cm in diameter), ringed; leaves pinnate, 2–3 m long, arched; leaf-divisions whitish beneath; inflorescence 30 cm long, much branched, drooping. Native of E. Australia, sometimes cultivated, known as 'Alexandra palm''.

*Areca catecu* L.
Stem solitary, slender and ringed, to 10 m high; leaves pinnate, 1.2–2 m long, the lower ones usually drooping; inflorescence much branched; male flowers in one row, with 6 stamens; females at the base of branches; fruit ovoid, 3–6 cm long, orange or red. Native country uncertain, cultivated in villages. Sliced nut is wrapped in a betel leaf (*Piper betel* L.) with a little dash of lime and chewed. Vern. *Pinang*, betel nut, 檳榔 . (Note: the species name often misspelt as '*catechu*').

*Areca triandra* Roxb.
Like the above, but male flowers arranged in 2 rows, with 3 stamens in each flower. Native of tropical Asia, occasionally cultivated as ornamental.

*Arenga pinnata* Merr.
Stem solitary, to 20 m tall, commonly covered with old leaf-bases; leaves pinnate, 5–6 (– 10) m long, with black fibres at the base; inflorescence arising among the leaves, pendulous; sugary liquid exuded from the cut of the young inflorescence; fruit round, 4–5 cm across. Probably a native of eastern India, formerly called *Arenga saccharifera* Labill. Vern. *Kabong*, sugar palm, 桄榔 .

**Calamus densiflorus** Becc.
Clustering high climbing rattan with stem reaching 40 m tall; pinnate leaves 1.1 m long, curved; leaflets up to 60 pairs; sheath bright to yellowish green, densely armed with spines; male and female inflorescences axillary, superficially similar, with tubular sheath (or spathe); fruit ovoid, 2 by 1.2 cm, covered in rows of scales. In forests, Gardens' Jungle, Bukit Mandai (*Ridley 6280*). Vern. *Rotan chichi.*

**Calam. diepenhorstii** Miq.
Gardens' Jungle, Bukit Timah (*Ridley s.n.* in 1907).

**Calam. erinaceous** (Becc.) Dransf.
Formerly called *C. aquatilis* Ridl. Ponggol, Holland Road, Gardens' Jungle, Changi (*Ridley 6275*). Vern. *Rotan bakau.*

**Calam. insignis** Griff.
Bukit Timah (*Ridley s.n.* in 1892), Gardens' Jungle. Vern. *Rotan batu.*

**Calam. javensis** Bl.
Kranji, Bukit Timah (*Ridley s.n.* in 1896).

**Calam. laevigatus** Mart.
Formerly called *C. pallidulus* Becc. Jalan Bray (*Ridley 6281*), Bukit Timah, Bukit Mandai.

**Calam. lobbianus** Becc.
Seletar, Bukit Timah (*Ridley 8961*), Chan Chu Kang, Pulau Damar.

**Calam. lucidus** Becc.
Formerly called *C. laxiflorus* Becc. Woodlands (*Ridley 12607*).

**Calam. ornatus** Becc.
Bukit Timah (*Ridley 11581*).

**Calam. oxleyanus** T. & B.
Bukit Timah (*Ridley 11463*), Tuas.

**Calamus ridleyanus** Becc.
Mandai (*Ridley 3504*, syntype), Gardens' Jungle.

**Caryota mitis** Lour.
Clump-forming palm; stems to 4 m tall; leaves twice pinnate, 1–1.75 m long; leaflets flat, all widening outward to a blunt tip, fish-tail like; male and female flowers in same inflorescence; inflorescences both terminal and axillary, developing from top downward, the stem slowly dying after flowering. Common in forests all over the island. Vern. *Tukas*, Fish-tail palm.

*Chrysalidocarpus lutescens* (Bory) Wendl.
Stems slender, ringed, 5–6 m tall, in clumps; leaves pinnate, 1–1.2 m long, with yellow rachis; inflorescences among the leaves, male and female flowers in small clusters; fruit ovoid, 3–4 cm long, yellow. Native to Madagascar; commonly cultivated in pots or on ground, always remaining in vegetative state. 黄椰子 .

*Cocos nucifera* L.
Stem solitary, ringed, often curved and leaning, to 30 m tall; leaves pinnate, 2–6 m long, with numerous pairs of narrow leaflets; flowers in branched spikes among the leaves; female flowers near the base of the branches; fruit ovoid globose, more or less trianglular, 20–30 cm across, edible. A very useful plant, widely cultivated all over the tropics; true home uncertain, it has been suggested that it is a native of the Indian Ocean. Vern. *Kelapa*, Coconut tree, 椰子 .

**Cyrtostachys renda** Bl.
Formerly called *C. lakka* Becc. Clump-forming palm; stem erect, slender to 10 m or more tall, prominently ringed; leaves pinnate, to 1.5 m long; sheath scarlet; one female flower flanked by 2 males, in panicles below the leaves; fruit small, ellipsoid, 8 × 4 mm, with a narrowed top. Formerly found in wet places near the sea, Kranji, Tuas, Chua Chu Kang, now extinct, but commonly cultivated in gardens. Vern. *Pinang raja*, Sealing Wax Palm, 猩紅椰子 .

**Daemonorops angustifolia** (Griff.) Mart.
Clustering, high climbing rattan, with stem reaching 40 m tall; pinnate leaves 2–3.5 m long; sheath greenish brown, densely covered with triangular, black spines; male and female inflorescences similar, terminal; spathe boat-shaped; fruit globose, to 1.8 cm across, covered in rows of reddish brown scales. In forests, Chua Chu Kang, Chan Chu Kang (*Ridley 4622*), Bukit Timah, Bukit Mandai. Vern. *Rotan sepat.*

**Daem. didymophylla** Becc.
Mandai, Changi (*Ridley 6273*), Chan Chu Kang, Seletar, Gardens' Jungle. Vern. *Rotan hudang.*

**Daem. grandis** (Griff.) Mart.
Seletar, Ang Mo Kio, Bukit Mandai, Bukit Timah, Bukit Arang (*Ridley 1660*), Gardens' Jungle, Changi.

**Daem. hystrix** (Griff.) Mart.
Bukit Mandai (*Ridley 3480*) Jurong, Sungei Murai, Gardens' Jungle, Seletar, Kranji, Tuas, Yio Chu Kang. Vern. *Rotan sabite.*

**Daem. leptopus** (Griff.) Mart.
Kranji, Bukit Mandai, Bukit Panjang, Jurong, Bukit Arang, Ang Mo Kio (*Ridley s.n.* in 1894). Vern. *Rotan bakau.*

**Daem. longipes** (Griff.) Mart.
Seletar, Bukit Timah (*Ridley 6902*), Bukit Mandai, Changi, Chan Chu Kang. Vern. *Rotan sepah, Rotan chochor.*

**Daem. micracantha** (Griff.) Becc.
Bukit Timah (*Ridley s.n.* in 1900).

**Daem. periacantha** Miq.
Bukit Mandai, Tuas, Bukit Timah (*Ridley 3492*).

*Elaeis guineensis* Jacq.
Short trunk of young trees covered with leaf-bases after the old leaves have been removed; slow-growing old trunk to 3–10 m tall, often dented with leaf-scars; leaves pinnate, arched, 4–5 m long, the lowest leaflets becoming thorns; cylindric male and globose female inflorescences borne on the same plant; fruit orange-red, in globose clusters 30–45 cm across. Oil from the fibrous oily pulp around the seeds is used for cooking and industrial uses. Native to West Africa. Vern. *Kelapa bali*, Oil Palm, 油棕 .

*Hyophorbe verschaffeltii* Wendl.
Also known as *Mascarena verschaffeltii* L. H. Bailey. Trunk solitary, ringed, 3–4 m long, swollen above, not at the base (thus called 'Bottle palm'); leaves pinnate, 1–2 m long; inflorescences below the leaves. Native of the Mascarene Islands.

**Iguanura ferruginea** Becc.
Small solitary or clustering undergrowth palm; stem very short or nearly absent; leaves pinnate, 1 m long, with a much larger terminal leaflet; male and female flowers crowded in groups on a simple or branched inflorescence. In forests, Gardens' Jungle, Bukit Timah.

**Iguan. geonomaeformis** Mart.
Stem 1–2 m tall; leaves bifid or 2–9-lobed, very variable. In forests, Bukit Timah, Chan Chu Kang.

**Korthalsia echinometra** Becc.
Clustering high-climbing rattan; stem often more than 30 m tall; leaves to 1.8 m long, with terminal thorny extension to 70 cm long; leaflets up to 25 pairs, narrowly elongate, greyish white beneath; inflorescences crowded in axils of uppermost leaves, to 60 cm long; fruit ovoid, 2.5 by 1.5 cm, covered by many vertical rows of reddish-brown scales. In forests, Bukit Timah, Chan Chu Kang (*Ridley 3521*). (*Korthalsia* is well-known as a genus of ant-plants. Ants inhabit the inflated ochrea of the leaves).

**Korth. grandis** Ridl.
Seletar (*Ridley s.n.* in 1894, lectotype), Bukit Panjang.

**Korth. rigida** Bl.
Also called *K. polystachya* Mart. and *K. wallichiaefolia* Wendl. Bukit Timah (*Ridley 6674*).

**Korth. scaphigera** Griff. ex Mart.
Seletar, Woodlands, Bukit Timah (*Ridley 6272*). Vern. *Rotan simut.*

**Licuala ferruginea** Becc.

Small fan palm; stem very short; leaves divided to the centre; leaflets 10–13, the central one the largest, to 1 m long; petioles about 1 m long, thorny at base; panicles 50–60 cm long; spathe brown, pubescent. In forests, Gardens' Jungle. Bukit Timah.

*Lic. grandis* Wendl.

Slender palm, 1–2 m tall; leaves orbicular, to 1 m across, nearly entire except the edges; petioles 1 m long, spiny. Native of New Hebrides and New Britain, often cultivated.

**Lic. spinosa** Wurmb.

Bushy palm, in clumps, 2–5 m tall; leaves orbicular; leaflets 15–18, linear, 30 cm long; petioles 1 m long, thorny the entire length; panicles erect or arching. In open dry places or swampy areas, Pulau Ubin, Pulau Brani.

**Lic. triphylla** Griff.

Stemless; leaves divided into 3–7 leaflets, 20–22 cm long; petioles slender, 30–40 cm long, sparsely thorny. In forests, Changi.

*Livistona chinensis* R. Br.

Solitary palm; trunk stout, ringed, to 15 m tall; leaves fan-shaped, nearly rounded, wider than long, 40–50 cm wide, divided to about the middle of the blade; petioles spiny; flowers bisexual, in panicles; fruit ovoid (2 × 1.5 cm). Native of S. China, planted. 蒲葵 .

**Liv. kingiana** Becc.

Leaves 1.5 m across, with a few divisions down to the central rib, mainly in the lower quarter; leaflets widening outwards, wedge-shaped; petioles massive, to 1.5 m long, spiny in lower parts; fruit globose, 5–6 cm across. In swampy forests, Chan Chu Kang, Bukit Mandai. Formerly called *Pholidocarpus kingiana* Ridl.

*Liv. rotundifolia* (Lamk.) Mart.

Trunk to 20 m tall; leaves 1.2 m long; tips of leaf-divisions forked halfway down; fruit globose, 2 cm across. Native of E. Malesia, cultivated.

*Liv. saribus* (Lour.) Merr. ex Cheval.

Trunk to 30 m tall; leaves to 1.2 m across, leaf-divisions almost reaching the central rib; fruit globose, 1.5–2 cm across. Native of Indo-China and several parts of Malesia, cultivated.

*Metroxylon sagu* Rottb.

Stout tree, forming big clumps, to 10 m tall; leaves pinnate, massive, to 5 m long, with about 60 pairs of strap-shaped leaflets; flowers in large terminal, wide-spreading panicle; male and female flowers mixed. Native to Moluccas and W. New Guinea, formerly cultivated for the starch.

**Myrialepis scortechinii** Becc.

Climbing thicket-forming rattan, to 40 m tall; young stems with horizontal rows of spines; whole leaf 3–5 m long, with terminal thorny extensions to 1.5 m long; male and female inflorescences on separate plants, arising from the nodes of uppermost reduced leaves; fruit depressed globose (3 × 2.5 cm), tipped with black stigmas and covered with myriads of tiny scales. Bukit Mandai (*Ridley 5860*), Chan Chu Kang, Kranji, Bukit Timah. Vern. *Rotan kertong.* Called *Plectocomiopsis annulatus* Ridl. and *P. scortechinii* (Becc.) Ridl. in Ridley's Flora.

**Nenga pumila** (Mart.) Wendl.

Also called *N. wendlandiana* Scheff. Tufted dwarf palm, 3–5 m tall; leaves pinnate, to 1.5 m long; leaflets linear, petiole 20 cm long, with a purplish sheath;

inflorescence usually 3-branched; fruit ovoid, 2–2.5 cm long, yellow to bright red. In forests; Changi, Seletar. (Note: *Nenga* is very similar to *Pinanga*, but differs from it in : 1) inflorescence with one spathe; 2) flowers always spirally arranged; 3) seeds laterally arranged).

**Nypa fruticans** Wurmb.
Rhizome very stout, creeping in mud; aerial stem very short; leaves pinnate, 5–6 m long, erect; inflorescence subterminal, erect, stalk 1 m long; fruits chestnut brown, in a globose cluster, 20–25 cm across. In tidal river, often forming large colonies. A very useful plant, leaves are used for roofing; sugar and alcohol can be obtained from the flower spikes; and the endosperm of the seed is edible. Vern. *Nipah*, 水椰 . (The generic name usually incorrectly spelt as *Nipa*).

**Oncosperma horridum** (Griff.) Scheff.
Tall slender palm, in clusters, with very dense crowns; stems to 20 m tall, covered with massive downward directed black spines; leaves pinnate; leaflets horizontal or nearly so; inflorescence large, below the leaves; flowers unisexual, spirally arranged; fruit round, ripening black, 1.5 cm across, waxy. In inland forests, Bukit Timah, Water Catchment Areas, Changi. Vern. *Bayas.*

**Oncosp. tigillarium** (Jack) Ridl.
Formerly called *O. filamentosum* Bl. Like the above species, but (1) leaflets drooping, and (2) often near the coast, standing in or near salt or brackish water. Tanglin, Changi, Kranji, Vern. *Nibong.* (Note: There is relic stand of Nibong palms near the main gate of the Istana).

**Pinanga disticha** Bl. ex Wendl.
Small forest undergrowth palm, often forming large clumps; stem very slender, to 1.3 m tall; leaves V-shaped, 20–30 cm long, simple or occasionally pinnately divided into broad or narrow leaflets; flowers in threes (with a female and 2 males), on a simple spike, 10 cm long; fruit ellipsoid, about 1 cm long; ripening red. In forests, Seletar.

**Pin. limosa** Ridl.
Usually solitary, 1–2 m tall; leaves oblong in outline, with deeply forked tip, about 30–40 cm long, entire or divided into irregular broad leaflets with curving sides. In muddy spots in dense forests, Bukit Timah, Seletar.

**Pin. malaiana** (Mart.) Scheff.
In small clumps; stem 30–50 cm tall; leaves broad, spreading, 30 cm long, pinnate; leaflets with 2 main nerves. In forests, Chan Chu Kang.

**Pin. simplicifrons** (Miq.) Becc.
Tiny palm, often forming large clumps; stem slender, winding, usually less than 1 m tall; leaves entire, oblong, deeply forked, 20–25 cm long. In forest.

**Pin. singaporensis** Ridl.
Stem tufted, 2–5 m tall; leaves pinnate, 1 m long; leaflets about 13, sigmoid. Formerly found in Bukit Timah, Bukit Mandai and Seletar, probably extinct sometime ago.

**Pin. subruminata** Becc.
Slender palm, to 1.3 m tall; leaves simple, V-shaped. In forest, formerly collected in Kranji.

**Plectocomia griffithii** Becc.
Solitary climbing rattan, to 50 m tall; whole leaf to 7 m long, including a terminal thorny extension to 3 m long; sheath green, armed with combs of brown spines;

leaflets to about 60 on each sides; male and female inflorescences similar, terminal; fruit globose, to 1.5 cm across, covered with rows of red-brown scales. Seletar, Kranji, Bukit Mandai (*Ridley 3470*). Vern. *Rotan dahan.*

**Ptychoraphis singaporensis** Becc.

Slender palm; stems 2–3.5 m tall; 2–3 in small clumps; leaves pinnate, 1–1.7 m long, with numerous leaflets; inflorescences 1–3, in leaf axils, 30–40 cm long; fruit fleshy, red, ellipsoid, 1–2 cm long. In forests, Tanglin, Sungei Buluh, Tuas. Vern. *Kerintin, Rintin.*

*Ptychosperma macarthurii* (Wendl.) Nichols

Trunks bamboo-like, to 6 m tall; leaves once pinnate, with many rather broad leaflets (7–20 cm long, blunt). Panicles below the leaves, 40–45 cm long; female flowers flanked by the males; fruit ellipsoid, orange, 1.2–1.5 cm long; seeds 5-grooved. Native of New Guinea, commonly cultivated in gardens. Seeds dispersed by birds, naturalized. Another species, *P. sanderianum* Ridl., with much narrower leaflets, is occasionally planted.

*Raphia farinifera* (Gaertn) Hylander

Stem annulate, unarmed, robust, to 15 m tall; leaves pinnate, very large, up to 15 m long, leaflets of variable sizes, the larger ones 2.4–3.6 m long. Native of Madagascar, formerly called *R. ruffia* (Jacq.) Mart.

*Rhapis excelsa* (Thunb.) Henry (= *R. flabelliformis* L. Hér.)

Trunks slender, straight, 2–4 m tall, in clumps, usually covered with fibrous leaf-sheaths; leaves fan-shaped, about 30 cm across, dark green, shining; leaflets 5–11, the ends blunt and toothed, rarely flowering under our climate. Native of S. China, planted in gardens or treated as 'dwarf plants' in pots. 棕竹 . Another cultivated species, *R. humilis* Bl., is a smaller plant, with smaller leaves of only about 6 leaflets.

*Roystonea oleracea* (Jacq.) Cook (= *Oreodoxa oleracea* Mart.)

Like *R. regia*, but much taller and the trunk is swollen only at the base, the crown of leaves also spreads in all directions. Less commonly cultivated than *R. regia.* Native of Barbados, called 'Cabbage Palm'.

*Royst. regia* (H.B.K.) Cook (= *Oreodoxa regia* H.B.K.)

Trunk columnar, greyish, ringed, to 20 m tall, slightly swollen at the base and middle; leaves pinnate, 3 m long, arched; male and female flowers growing along spikes in a large panicle. Native of Cuba, often planted in rows as avenue trees, noted for its stateliness and elegance, thus called 'Royal Palm', 皇椰子 .

**Salacca affinis** Griff.

Stems stout and short, sometimes appearing stemless, in clumps; leaves pinnate, in big, dense rosettes, 3–4 m long; leaflets flat, in one plane, oblong, 30–40 cm long; flowers unisexual, dioecious, in erect spikes subtended by large spathes; fruit globose, about 2.5 cm across, beaked, scaly; seeds 1–3, enbedded in a juicy pulp. In wet spots in forests, Bukit Timah, Chan Chu Kang (*Ridley 4421*). Vern. *Salac.* (The generic name sometimes incorrectly spelt as *Zalacca*). Imported fruits from Indonesia of a related species, *S. edulis* Bl., are sometimes sold in markets.

**Sal. conferta** Griff

Differs from *S. affinis* in having linear leaflets arranged in 2 planes, and male and female flowers on the same inflorescence, forming a massive terminal head. In swampy forests, often forming thickets, Tanglin, Bukit Timah, Changi, Chan Chu Kang (*Ridley 3143*) Jurong. Vern. *Asam payah, Salak hutan*. (This plant differs from other species of the genus in having terminal inflorescences thus re-named as *Eleiodoxa conferta* (Griff.) Burret. in some literature.)

# Resolving Iron Deficiency in *Wrightia religiosa* by Foliar Analysis and its Amelioration Using an Iron Chelate as a Soil Additive

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## Abstract

Iron deficiency in *Wrightia religiosa* was associated with a suboptimal level of "active Fe" in the young leaves. Soil application of Nervanaid Fe 132, a carrier of FeEDTA, at 10 g per plant and particularly at 20 g per plant helped chlorotic plants to regain their healthy vigour. Treatment brought the "active Fe" to levels comparable to or above those of the control.

## Introduction

*Wrightia religiosa* is a popular ornamental shrub in Singapore because of its fragrant flowers and ease of propagation. It is also a popular choice for bonsai. Recently, a noticeable population of *Wrightia* established in parks and along roadsides has been affected by iron deficiency. Iron deficiency was confirmed by partial recovery of deficient plants upon foliar treatment with $FeSO_4$.

Iron deficiency symptoms manifest themselves initially as interveinal chlorosis of the young leaves as iron does not move readily from old leaves to the young flushes. Iron is required for chlorophyll synthesis and when it is present at suboptimal level, insufficient chlorophyll is synthesized thus causing chlorosis (Plate 1). As deficiency becomes more advanced and acute, the affected young leaves grow to become the older affected leaves, while the newly emerged flushes remain chlorotic. Eventually, the entire plant assumes an overall chlorotic appearance (Plate 2). In very severe cases, the leaves become almost bleached of colour and have random necrotic spots. Dieback of growing tips is common (Plate 3).

A spectrum of physical and chemical soil properties has been identified as conducive to iron deficiency in plants (Chaney, 1984; Lindsay, 1984; Lindsay and Schwab, 1982; Mortvedt et al., 1977 Vejsadova et al., 1982). The iron chelate, FeEDTA, is known to be an effective soil additive in overcoming iron chlorosis where the soil pH is below 6.70 (Lindsay and Schwab, 1982). This investigation critically examined the efficacy of this fertilizer in resolving iron chlorosis in *Wrightia* thriving on acid soil.

## Materials and Methods

The trial area was located in a park where there was a concentration of iron-deficient *Wrightia* plants. The sites were characterized by acidic soil pH values ranging from 4.00 to 6.70.

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The iron chelate, Nervanaid Fe 132 (a.i. FeEDTA, 12.7% Fe) was tested at the rates of 10 g per shrub and 20 g per shrub respectively. Five trial plants were used for each treatment and control. The chelate was dissolved in 5 l of tap water and then poured evenly around the area spanned by the plant. In the case of the control, only tap water was used. Treatment began at zero time after the first foliar sampling and was thereafter maintained at weekly intervals for 4 weeks. Where *Wrightia* plants existed in groups, each trial plant was selected in such a manner that it was separated from the next by at least one guard plant so that the risk of spillover of treatment effect was minimized.

From preliminary analyses, no relationship was discernible between total foliar Fe content and iron chlorosis. In many cases, chlorotic plants were found to have significantly more total Fe than their healthy counterparts. This was consistent with the findings of Bennett (1945) and DeKock et al. (1979). However, the "active Fe" fraction extractable by 1N HC1 showed distinct differences between healthy and deficient young leaves. This parameter was monitored during the course of treatment.

Foliar sampling was done three times i.e. at zero time, week 2 and week 4. Only the first two pairs of fully-developed young leaves were sampled for analysis. These were washed with Teepol (a non-ionic detergent), 0.1N HC1 and finally rinsed with deionized water. Fresh subsamples were cut into small pieces with a pair of stainless steel scissors, dried between filter papers and weighed out in duplicates. Each 1 g sample was extracted with 20 ml. of 1N HC1 for 24 hours with occasional agitation (Takkar and Kaur, 1984). "Active Fe" was analysed by the PU9000 AA spectrometer immediately after filtration.

## Results and Discussions

Results were subjected to the Duncan Multiple Range Test for significance and are presented in Table 1 and Histogram 1.

Table 1

Changes in the "active Fe" fraction in ppm in fresh young leaves upon treatment with Nervanaid Fe 132

| Time (Week) / Treatment | 0 | 2 | 4 |
|---|---|---|---|
| Control | 19.96a | 22.94a | 22.34a |
| 10 g chelate | 13.40b | 19.40a | 23.48a |
| 20 g chelate | 11.12b | 22.96a | 30.36b |

For each column: Values with the same letter are not significantly different at $P < 0.01$.

Before treatment at zero time, iron-deficient plants had significantly lower 1N HC1 - extractable Fe or "active Fe" than the control plants (Table 1 and Histogram 1). A typical iron-deficient *Wrightia* plant is depicted on Plate 1.

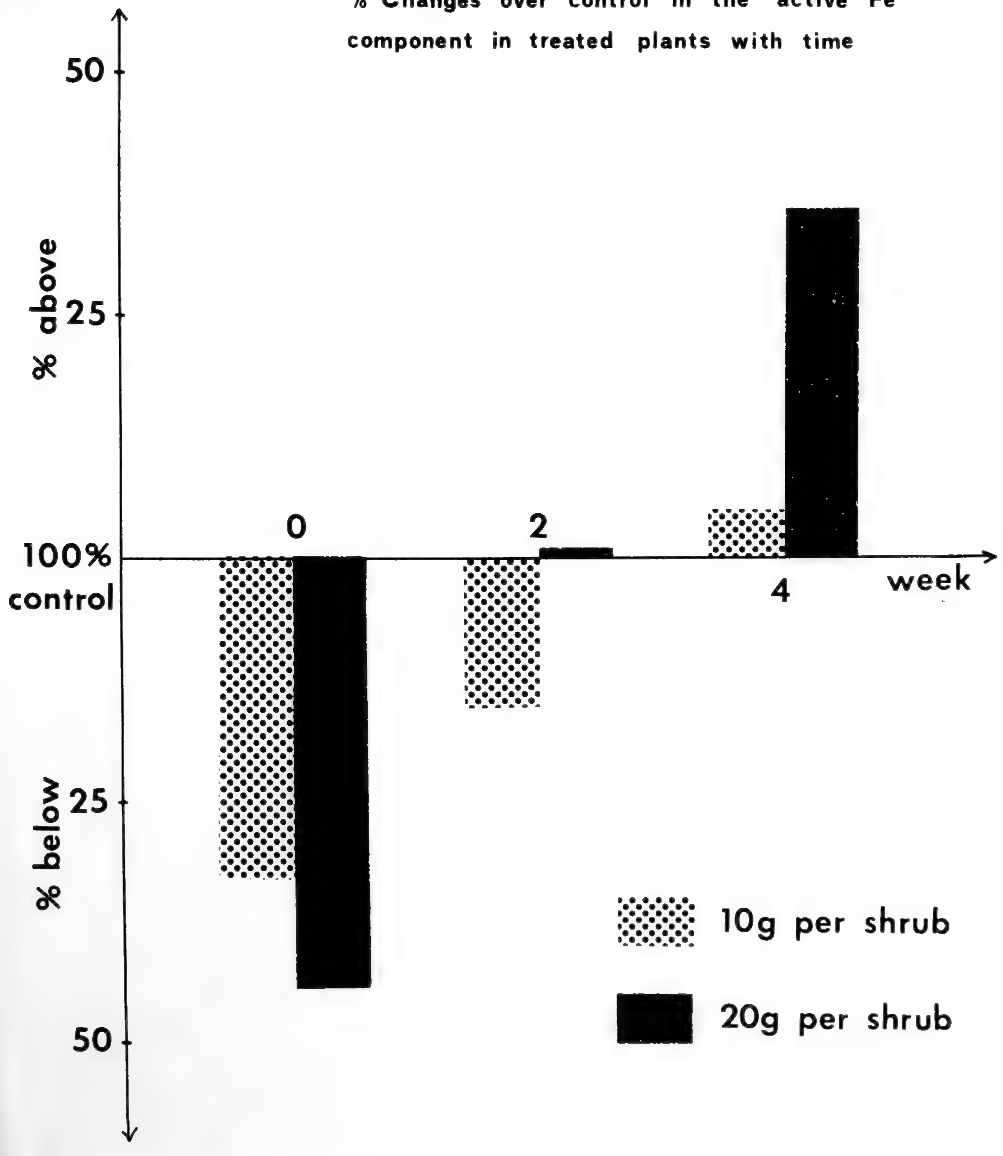
After two applications of the iron chelate, foliar analysis revealed that the "active Fe" fractions in treated plants became comparable to those in the controls at week 2. The significant increase in "active Fe" in treated plants concurred with a pronounced recovery from iron chlorosis. This was especially remarkable with the 20 g treatment. At this stage, the new flushes assumed the healthy green colouration.

However, the older leaves remained chlorotic. The recovering process appeared to take effect over the first and second week (Table 1 and Histogram 1).

At week 4, the treated plants had attained satisfactory recovery. With the 20 g chelate treatment, the "active Fe" had significantly risen to 35.9% above that of the control. "Active Fe" contents in the controls and plants treated with 10 g chelate were similar although somewhat higher in the latter. (Table 1 and Histogram 1).

The longevity of treatment effect was monitored after the cessation of treatment at week 4. Plants treated with 20 g chelate remained healthy for at least 6 months whereas those treated with 10 g chelate reverted to the original state of iron chlorosis after 2–3 months.

**HISTOGRAM 1 :**



**% Changes over control in the "active Fe" component in treated plants with time**

Plate 1: Mild iron deficiency in *Wrightia religiosa*

Plate 2: Advanced iron deficiency in *Wrightia religiosa*

Plate 3: Dieback of growing tips in advanced iron chlorosis in *Wrightia religiosa*

## Conclusion

In agreement with the findings of Hellin et al. (1987) and Wallace et al. (1984), the present study showed positive results in the amelioration of iron chlorosis in *Wrightia religiosa* with FeEDTA as a soil additive where the soil pH was acidic. Both levels of Nervanaid Fe 132 tested were found to be effective in correcting iron deficiency. The higher dosage, however, should be used as its ameliorative effect was more persistent.

It was possible to resolve iron chorosis in *Wrightia* by determining the 1N HCl - extractable Fe or "active Fe". The likely sufficient level of this component that is compatible with normal growth in *Wrightia* is about 20 ppm on a fresh weight basis (Table 1).

Further investigations are in progress to resolve iron chlorosis in *Wrightia* by soil analysis. The ultimate solution for iron chlorosis in *Wrightia* lies in determining whether the deficiency is true or induced. If it is induced deficiency, the cause needs to be ascertained so that suitable corrective measures could be administered accordingly.

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# Chemical Growth Retardation of *Baphia nitida* with PP333

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## Abstract

PP333 (common name paclobutrazol), [(2RS, 3RS)-1- (4-chlorophenyl)-4, 4-dimethyl-2-(1,2,4-triazol-1-yl-) pentan-3-o1)] was tested on *Baphia nitida* hedges to evaluate its effects on growth. Results show that growth of *B. nitida* was retarded without phytotoxicity symptoms at the rates of PP333 applied. Growth retardation of up to six months was achievable at the PP333 rates tested, making chemical growth control a useful tool for the maintenance of such hedges at reduced manual pruning and related labour costs.

## Introduction

PP333 is a broad spectrum growth retardant which acts by inhibiting gibberellin biosynthesis and reducing cell division and extension (Lever et al. 1982; Sugavanam 1984). It is xylem mobile and its effects include overall stunting of the plant, with shorter internodes and darker green leaves (Sugavanam 1984); it also has good fungicidal activity.

PP333 has been used on a variety of crops including graminaceous crops like wheat, barley and rye (Froggatt et al. 1982) in stem shortening properties to reduce lodging, and in fruit trees to reduce pruning requirements. In apples, growth retardation became apparent about 1½ months after treatment and shoot growth of treated plants was about 48% that of the untreated (Lever et al. 1982). Ornamental greenhouse crops like *Begonia*, *Chrysanthemum*, *Hibiscus*, *Coleus* etc were dwarfed by PP333 without any phytotoxicity symptoms (Shanks 1980).

*Baphia nitida* is widely planted in Singapore, being used for screening purposes. Much labour is expended in manual pruning to maintain the desired height and lateral spread of the hedges. This paper reports a study conducted in the Singapore Botanic Gardens into the use of chemical growth retardation to control the vegetative growth of *B. nitida* with the aim of reducing the frequency of manual pruning.

## Materials and Methods

PP333 was tested at rates of 0 g (Control), 0.5 g, 1.0 g, and 2.0 g active ingredient per plant. A randomised complete block design consisting of three blocks was used. Each block contained four plots which were four stretches of established hedge, each about 10 m long and containing 30 plants. Plots within each block were spaced 2 m apart. The treatments were randomly assigned to the four plots in each block.

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The retardant was applied as a soil drench. A shallow trench, 3-5 cm deep, was dug around the base of each plant. PP333 at its desired rate, diluted in water, was poured into the trench which was then refilled with soil. Each plant received 150 ml of solution.

Only one application of retardant was carried out. The hedges were then left to grow and were pruned at regular intervals by the Singapore Botanic Gardens maintenance workers regularly deployed for hedge pruning operations. Pruned foliage were collected for dry weight determination. This was measured after the plant materials were dried at 100°C until constant weight.

## Results and Discussion

Pruning of *B. nitida* hedges was carried out 1, 3, 6 and 9 months after application of retardant. Dry weights of foliage pruned from all plots in the three blocks are shown in Table 1. As seen in Table 2 and Figure 1 there was no significant difference between all treatment means at the first pruning one month after PP333 treatment.

Table 1

| Sequence of pruning | No. of months after PP333 application | Dry weight, kg | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Block 1 | | | | Block 2 | | | | Block 3 | | | |
| | | T1 | T2 | T3 | T4 | T1 | T2 | T3 | T4 | T1 | T2 | T3 | T4 |
| 1st | 1 | 7.1 | 6.9 | 6.7 | 6.8 | 5.2 | 5.0 | 5.4 | 5.4 | 7.9 | 7.8 | 7.9 | 8.5 |
| 2nd | 3 | 0.8 | 1.0 | 1.3 | 7.0 | 0.6 | 0.6 | 0.8 | 5.6 | 1.4 | 1.3 | 1.4 | 7.9 |
| 3rd | 6 | 1.5 | 1.7 | 1.4 | 7.6 | 0.6 | 0.6 | 0.5 | 5.6 | 1.5 | 1.6 | 1.7 | 8.0 |
| 4th | 9 | 5.3 | 5.3 | 5.5 | 7.6 | 3.8 | 4.0 | 4.7 | 6.2 | 5.6 | 5.8 | 5.7 | 7.9 |

The trial started with the application of PP333 as a soil drench. Blocks 1, 2 and 3 were hedges in three different lawns at the Botanic Gardens. T1, T2, T3 and T4 refer to treatments of 0.5g, 1.0g, 2.0g and 0g (Control) active ingredient per plant respectively. Pruning of hedges was carried out 1, 3, 6 and 9 months after the trial started. Foliar material from individual plots were collected at each pruning for dry weight determination.

Table 2

| Sequence of pruning | No. of months after PP333 application | Paclobutrazol, g/plant | | | |
|---|---|---|---|---|---|
| | | 0.5 | 1.0 | 2.0 | 0.0 (Control) |
| 1st | 1 | 6.73a | 6.57a | 6.67a | 6.90a |
| 2nd | 3 | 0.93a | 0.97a | 1.17a | 6.83b |
| 3rd | 6 | 1.19a | 1.31a | 1.20a | 7.07b |
| 4th | 9 | 4.90a | 5.03a | 5.30a | 7.20b |

Dry weight readings in the 3 blocks/replicates were averaged. Going across the table, readings (at each pruning) with the same alphabet are not significantly different at the 1% level.

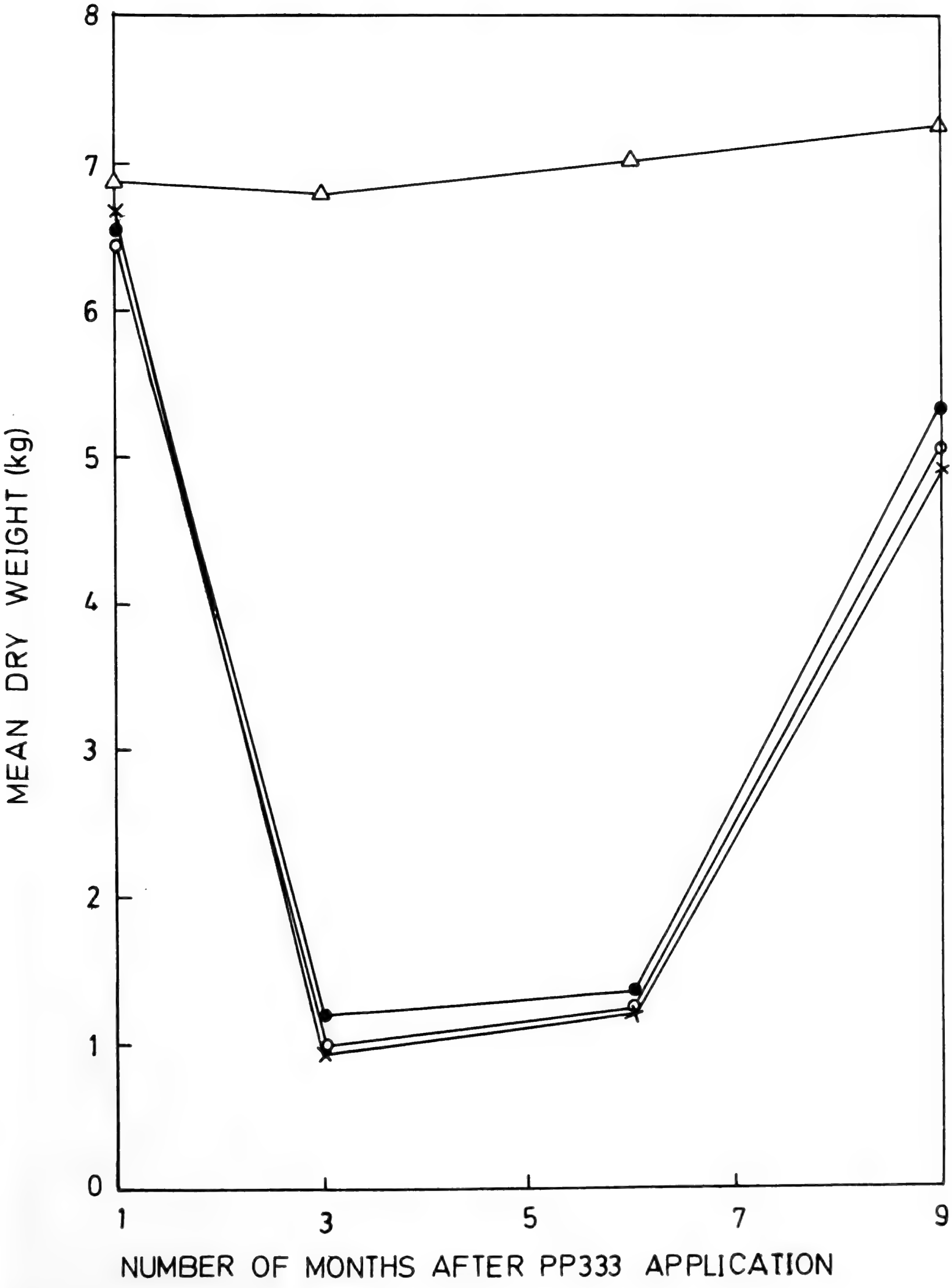

Fig. 1. Mean dry weight of foliage pruned during the duration of the trial; × - 0.5 g PP333/plant, ○ - 1.0 g PP333/plant, ● - 2.0 g PP333/plant, △ - control.

In the second pruning though, three months after PP333 treatment, a sharp and significant decrease in dry weights of foliage pruned from retardant-treated plots was observed. Growth retardation was equally effective at all three rates of PP333 tested. Subsequent prunings also yielded dry weight readings which were not significantly different for all three PP333 rates but were significantly different from the control readings. Visually a clear difference was seen between plant growth in control and treated plots (Figure 2).

Plants treated with retardant began to show signs of breaking out of retardation six months after the start of the trial. Although still compact in growth compared to the control plants, new actively growing shoots began to be produced. An increase in dry weight readings of foliage pruned from PP333 treated plots was found nine months after the start of the trial (Table 2 and Figure 1). Again the dry weights of foliage pruned from retardant-treated plots were not significantly different at all three PP333 rates but were significantly different from control readings. Nevertheless even the retardant-treated plots were growing considerably at this stage and were losing their compact and neat appearance.

Statistically the results show that all three rates of PP333 tested were equally effective in retarding *B. nitida* growth. However, visually it was seen that the higher rates of 1.0 and 2.0 g active ingredient per plant maintained a more compact and neater appearance of the plants for a longer period. To reduce chemical costs, the lower rate of 0.5 g per plant, found to effectively control growth for up to about six months, should be favoured.

To demonstrate the practicability of the 0.5 g per plant application rate, a 100 m long stretch of *B. nitida* hedge consisting of 300 plants was treated with this rate of

Fig. 2. Differences in vegetative growth of retardant-treated and control plants. The length of hedge on the right was given 0 g PP333/plant (control) while that on the left was given 0.5 g PP333/plant. The picture was taken just before the second pruning, 3 months after the start of the trial.

PP333. The plants were pruned one month after retardant application and no further pruning was subsequently done. Retardant application at the same rate was repeated six months after the initial application. Figure 3 shows the condition of the hedge one year after the trial began. The plants were compact in growth, had shorter internodes, darker green leaves and required a light pruning at most to restore uniform height for the hedge.

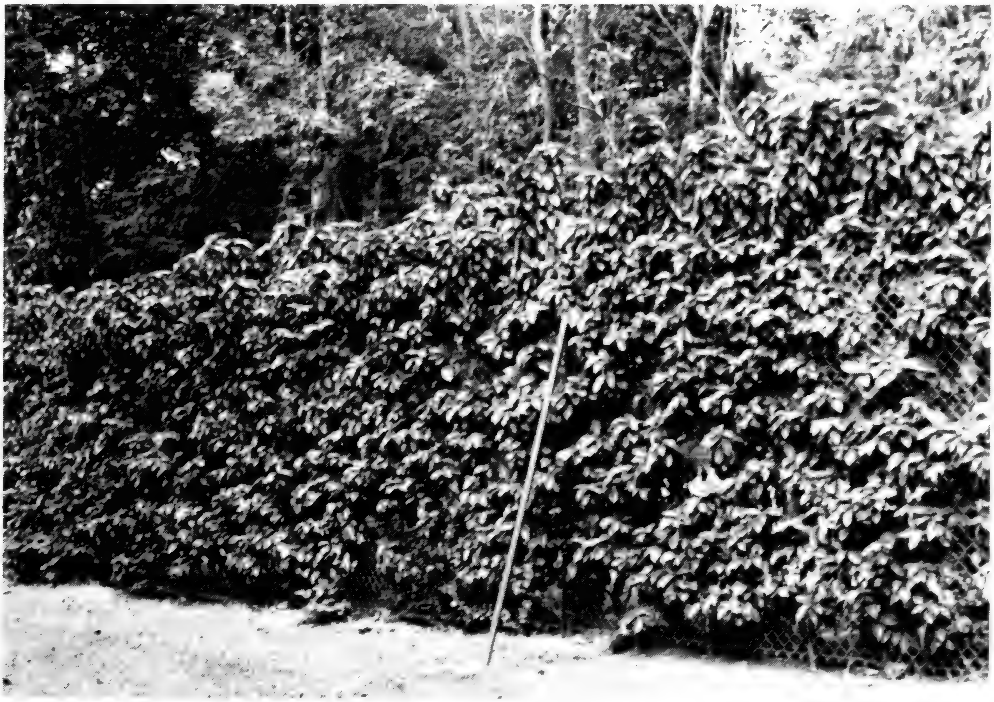

Fig. 3. PP333-treated hedge one year after retardant application. The hedges were treated with 0.5 g PP333/plant applied as a soil drench; application was repeated six months after the start of the trial. Except for one pruning one month after the first retardant application, no other pruning was done.

No phytotoxicity symptoms were encountered throughout the trial following retardant treatment. Application by soil drench was chosen because a preliminary trial showed that it effected greater retardation than foliar spray. McDaniel (1983), and Barrett and Bartuska (1982) also reported that soil drench was more effective than leaf application for *Chrysanthemum* and *Phaseolus*. It appears that the reduced effectiveness of PP333 applied to mature leaves suggests that it is less effectively translocated through the phloem compared to the xylem.

## Conclusion

The results reported here show that chemical growth retardation of PP333 is an effective tool for reducing the need for manual pruning of *B. nitida* hedges. This is expected to make maintenance of such hedges less manpower intensive, and when compared to costs for manual pruning, less expensive.

## Acknowledgements

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# Growth and Yield of Mango cv Golek in Java Over 25 Years

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## Abstract

Trunk cross sections of selected 'Golek' clones increased almost linearly from the age of 5 to 25 years at the high rates of 90 cm$^2$ and 70 cm$^2$ per year for nucellar seedlings and grafted trees respectively. Yields were extremely low and erratic and did not seem to affect tree growth. The highest yield levels occasionally attained by individual trees amounted to 1 fruit per cm$^2$ trunk cross section.

The 2 best seedling trees were far superior to the rest and about as fruitful as the best clone; the latter attained an aggregate crop of 3320 fruit and a trunk size of 1560 cm$^2$, against average values of 1765 fruit and 1580 cm$^2$ for the other grafted clones. Differences between clones were large but not sufficiently consistent to substantiate them. The results suggest that a similar analysis over the full 45-year experimental period (!) and including the clones of other cultivars in the trial, could be very worthwhile.

## Introduction

The mango collection at the Chukurgondang experimental farm near Pasuruan comprises about 200 cultivars: 72 from East Java, 64 from Central and West Java and 66 from other countries. The collection is unique because of the long period of observation (from 1941) and because tree growth has been recorded as well as yield. At the time several fruit tree collections were established by the Agricultural Extension Service (Terra, 1948), to test the suitability of different species and cultivars. Chukurgondang is situated in the centre of mango cultivation in East Java and the mango collection goes down to the clonal level in order to establish whether the tree population of a so-called cultivar is indeed uniform or not, and if not, whether clonal selection within the cultivar is worthwhile.

At Chukurgondang the original record books from 1941 are still in use. To find out whether a comprehensive analysis of this wealth of information might be worth the effort, such an analysis was carried out for the clones of a single cultivar, 'Golek', and over a 25-year period only. The results are presented in this paper.

## Materials and Methods

Pitoyo et al (1982) gave a general description of Chukurgondang Station. The farm is about 50 m above sea level. The area has a monsoon climate with a prominent dry season: average rainfall (1960–1981) from May to November amounts to only 220 mm, against 1140 mm during the remaining five months.

The trees are planted at 14 m square and now form a closed stand. The soil is sandy and deep, infertile, and with low water retention. Mango growers in the area prefer somewhat better soils. There is no irrigation. The orchard is clean-cultivated; fertilizers and manure have been applied mainly in the early years. The staff list several pests and diseases which cause serious fruit losses in some years (Pitoyo et al, 1982):

mango hoppers, fruit flies, mealy bug, bats and birds, anthracnose and sooty mould. The trees are too big for effective crop protection.

The selected 'Golek' clones in Chukurgondang are listed in Table 1. They are identified by a number and have all been propagated from a mother tree collection in nearby Pasuruan.

Table 1
Number of trees of the 8 clonal selections of cv Golek, year of planting and rootstock

| Clone Number | 31 | 33 | 35 | 133 | 177 | 195 | 229 | 255 |
|---|---|---|---|---|---|---|---|---|
| Trees on 'Madu' stock, planted in 1941 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Trees on 'Madu' stock, planted in 1956 | — | — | 3 | — | — | — | — | — |
| Nucellar seedling trees, planted in 1956 | — | — | — | — | — | — | 19 | — |

In addition to the 'Golek' selections, the collection comprises somewhat smaller numbers of 'Madu', 'Arumanis' and 'Manalagi' trees; numerous other cultivars are represented by pairs of trees of one or two selections only.

Annual records for each tree include:

- trunk girth, for the grafted trees at 10 cm above and below the union and for the seedling trees at the same height as the scion measurement;
- tree height and tree spread in the E-W and N-S directions;
- number and weight of fruit.

For this paper only the trunk girth and number of fruit per tree have been analysed, over a 25-year period from planting. Girth was converted to trunk cross section ('basal area'), assuming a circular cross section. Basal area brings out differences in size between trees better than girth or diameter (Verheij, 1972); differences in tree weight are generally somewhat greater than differences in basal area.

The trees of each clone are planted side by side; this arrangement and the low tree numbers per clone precludes statistical analysis.

## Results

Figure 1 depicts basal area growth and annual crop load for the three groups of 'Golek' trees listed in Table 1. As the trees grow older and bigger they can bear larger numbers of fruit. To be able to compare crop loads irrespective of tree size, the crop load has been expressed as the number of fruit per $cm^2$ basal area. Only crop loads exceeding 1 fruit per 8 $cm^2$ basal area are shown in Fig. 1.

The growth curves in Fig. 1 are rather straight. After a slight upswing in the first few years, the seedling trees grow at a rate of about 90 $cm^2$ per year against around 70 $cm^2$ for the grafted trees. Initially all trees planted in 1956 grow equally well, but after 5 years the superior vigour of the seedling trees becomes manifest.

The trees are extremely poor yielders. Clone 35 planted in 1956 comes out best, but even for this clone in half the years the crop is too light to be shown in Fig. 1. The seedling trees only produce a crop in excess of one fruit per 8 $cm^2$ basal area once in 25 years. It should be borne in mind that even a yield of one fruit per 2 $cm^2$ basal area is not at all high. In apples for instance, yields exceeding 1 $kg/cm^2$ trunk cross section are not uncommon (Verheij, 1972; Verheij and Verwer, 1972).

There is no indication in Fig. 1 of a relationship between yield and growth in the sense that in a fruitful year basal area growth is reduced. Nor is there evidence of

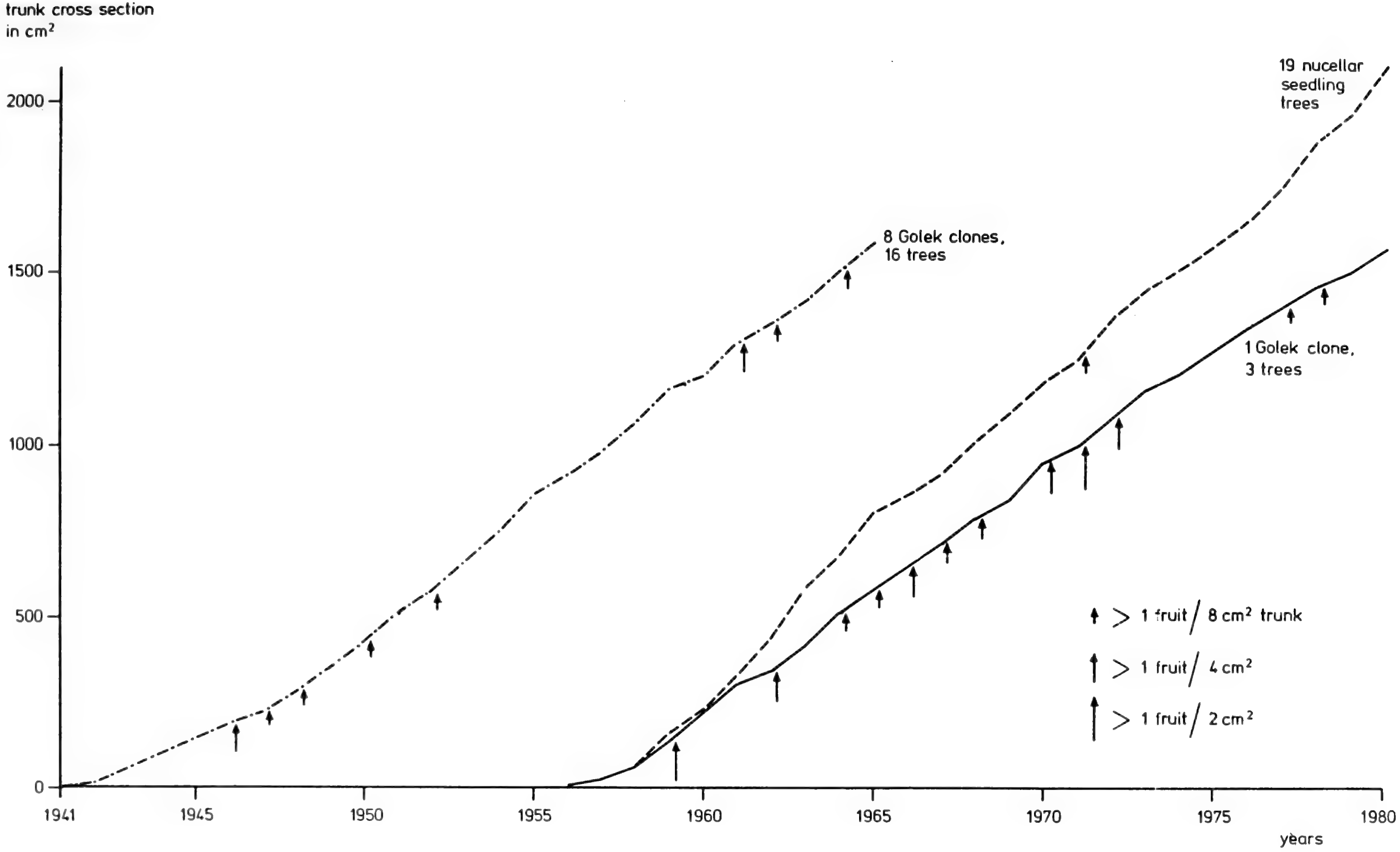

Fig. 1 Growth curves for the 3 groups of 'Golek' trees, and most fruitful years.

biennial bearing. Apparently the yield levels are too low to slow down growth. This even applies to the most fruitful individual 'Golek' trees, which in some years produced about 1 fruit per cm$^2$ basal area. Unfortunately trunk girth was measured in August, that is, between bloom and harvest. Consequently the effect of a heavy crop on trunk growth is spread over 2 years and therefore hard to trace.

In Fig. 2 the cumulated numbers of fruit over 15 and 25 years are plotted against basal area at these ages for all 'Golek' trees planted in 1956. The most fruitful trees are those which produce the highest number of fruit in relation to tree size. These trees have been marked by lines linking the values at 15 to 25 years.

This brings five outstanding trees to light: the three trees of clone 35 which stood out in Fig. 1 already, along with two nucellar seedlings of clone 229. These two deviate so much from the unproductive remainder that it is highly improbable that they belong to the same population; they may for instance be sexual instead of nucellar seedlings.

The two superior seedling trees are in league with the grafted trees of clone 35, which between them vary a great deal in size and yield, but form a trio through the parallel course of the lines, indicating that from age 15 to 25 all three trees were equally fruitful. The smallest grafted tree ($<1000$ cm$^2$ basal area at 25 years) and the one but largest seedling tree ($>2500$ cm$^2$ basal area) are the two most fruitful trees! After 25 years both trees have borne an aggregate crop of 2.75 fruit per cm$^2$ basal area

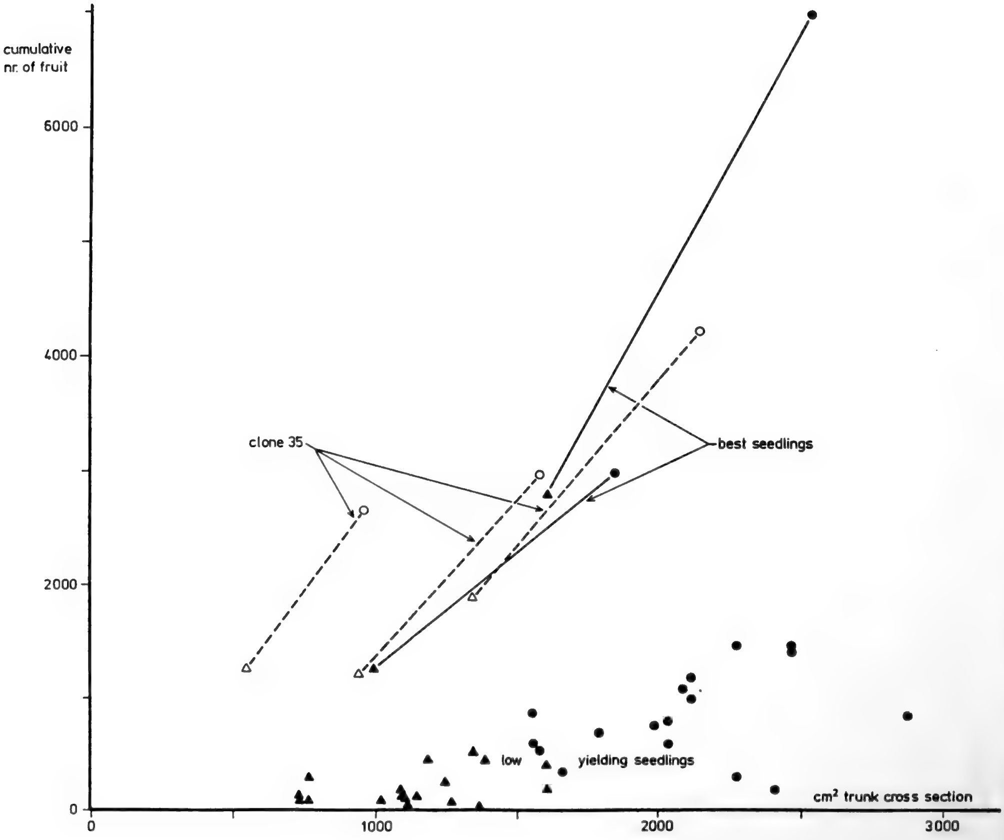

Fig. 2. Cumulative number of fruit against tree size, 15 (△) and 25 (○) years from planting, for each 'Golek' tree planted in 1956. Lines link values at 15 and 25 years for the most fruitful trees.

(although up to the age of 15 years the small tree had done much better than the large one in relation to its size).Planting density of the small tree would have to be nearly 2½ times as high to match the cumulated yield per ha of the large tree at 25 years. The difference in basal area suggests that a 2½-fold increase in number of trees per ha can indeed be accommodated. Higher yields per ha in the early years and easier management of the small trees no doubt would compensate for the cost of the extra trees.

In Fig. 3, growth and yield of all 'Golek' clones on 'Madu' stock are compared at intervals of 6 years.

Since yields in the early years are most important for the grower, the clones in Fig. 3 have been arranged in order of declining yield over the first 18 years; after 12 years the order was almost the same. For all clones planted in 1941 yields during the 13th to 18th year — when the trees should have been at their best — were particularly poor. Consequently the yield picture is largely determined by the crops produced during the last six-year period. Only clone 35 planted in 1956 was most productive in the 13th to 18th year. These trees have borne the largest aggregate crop, not only over 24 years, but throughout. On the other hand, trees of the same clone planted in 1941 produced less than half as much. Because of this large variability which was also found between trees within some of the clones, it is impossible to substantiate the observed differences between the clones.

Looking at the lower half of Fig. 3 it is clear that the differences between clones in the rate of growth were quite large. During the first six years, trees of the most vigorous clone grew three times as fast as trees of the weakest clone; the same holds for the last 6-year interval. However, the clones are not very consistent in their growth rates, so that the differences in tree size after 24 years are not so large. Clone 177 had the largest trees (of similar size as the seedling trees), clone 229 the smallest.

Fig. 3 also shows that there may, after all, be some interaction between tree growth and yield. This is revealed by the drop in tree size ranking with increasing age for the more productive clones on the left hand side, as against rank gains for the least productive clones on the right side. In other words: tree growth of the better yielding clones gradually lags further behind that of the lowest yielding clones. This trend is remarkably consistent. The logical explanation is that fruiting moderates growth, but the reverse — moderate growth promotes fruiting — cannot be ruled out.

## Discussion

In retrospect, the experiment was of course premature. The confusion over variations between and within mango cultivars was — and still is — a real problem. However, the role of virus diseases and other endemic infections has to be clarified before clonal selection can make headway. In this respect little progress has been made in the 45 years since the trial started.

The experiment is also much too weak to yield convincing conclusions in respect of the clones. So what is left is a unique long-term record of growth and yield of 'Golek' trees. Unfortunately the yields have been very low, in fact too low to affect growth sufficiently to study the relationships between growth and yield. Administrative problems during wartime and early independence may have left room for pilferage of fruit or casual recording. However, the consistency of the data per tree from year to year suggests that the records are generally sound and that the low yields are real.

The one serious omission is the lack of information on flowering, fruit set and early fruit drop, so that after all these years one can only speculate on the reasons for the poor crops. Probably paucity of bloom and destruction of inflorescences by pests (mango hoppers, tip borers) and diseases (anthracnose) are the main reasons

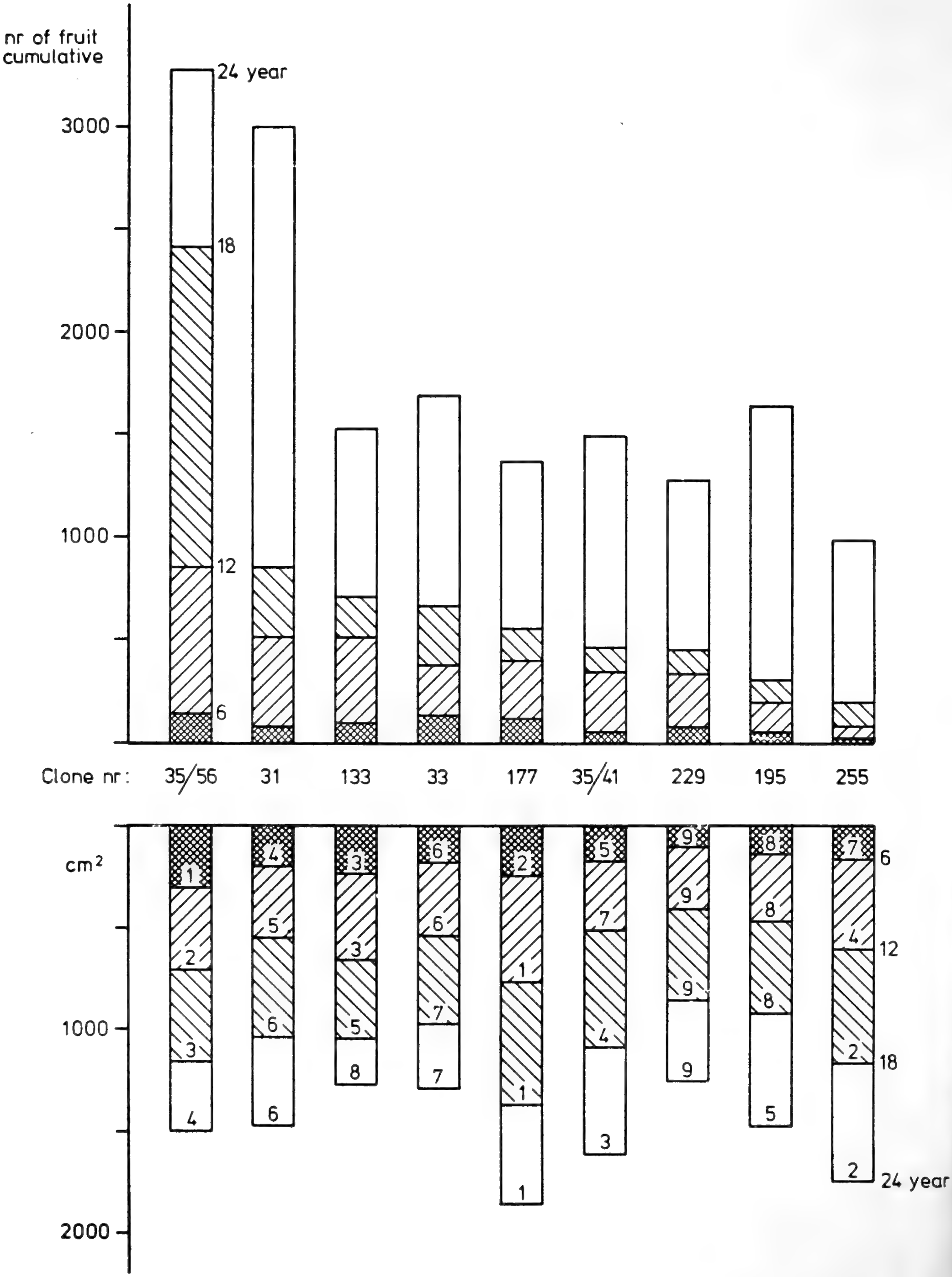

Fig. 3. Growth and yield of 'Golek' clones on 'Madu' stock.
Top: Mean number of fruit per tree, cumulated over 6-year periods.
Bottom: Mean trunk cross section per tree at 6-year intervals; numbers in the columns indicate ranking for tree size: 1 = smallest; 9 = largest.

for crop failure. While gathering the data for this paper in 1983, most inflorescences withered away owing to tip borer damage.

There are indications, at least in some cultivars, that twigs which have flowered will not flower the following year, irrespective of fruit set (Lal Singh and Abdul Aziz Khan, 1939). If this is the case, destruction of a heavy bloom by pests or diseases may therefore decimate the next crop as well as the current crop. Moreover crop failure invites untimely flushing, so that the terminal buds may not be receptive at the time of flower induction in the following year. Verheij and Snijders (1986) describe a similar sequence of events to explain the poor and erratic cropping of clove trees; picking the clove buds also deprives the tree from the stabilizing effect of a load of fruit on the growth rhythm. Current research in Australia aims at solving the riddles posed by erratic flowering in mango (Scholefield, 1983).

The seemingly straight growth curves of the trees probably should be interpreted as having the shape of a flattened S, because that is the common shape of trunk growth curves in forestry. Extending the curves up to the present day (45 years for the 1941 planting!) may settle this point. Westgarth and Buttery (1965) report the results of a spacing experiment with rubber trees over a 30-year period. Converting their girth data into basal area also produces flattened S-curves. The highest growth rates were attained at 5–15 years and ranged from 66 to 14 $cm^2$ per tree per year for the widest and closest spacings respectively. In comparison the mango growth rates of 90 and 70 $cm^2$ basal area increments are quite high.

It is concluded that the results of fast-growing, poorly cropping 'Golek' trees form a useful basis of reference, against which improvements in the yield : growth relationship, obtained under more intensive husbandry, can be measured. A further analysis of the Chukurgondang data is recommended, to cover the full 45-year period of recording and to compare growth and yield of 'Golek' with that of other leading cultivars.

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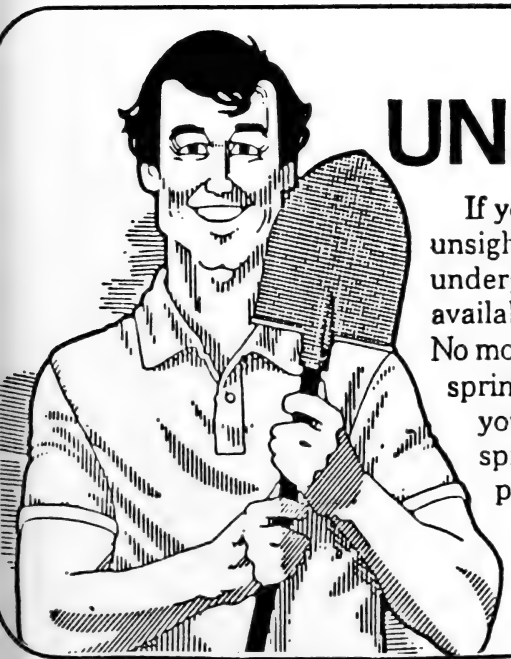

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