Ferns of Malaysian Rain Forest

A Journey Through The Fern World

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Contents

ABSTRACT

Ferns are seedless vascular plants which differ from gymnosperms and flowering plants as they do not have either seeds or flowers but reproduce via spores. They have many features similar to mosses and algae but are usually differentiated from these simpler plants as they have xylem and phloem for the conduction of water and food materials. They are most commonly found in moist, shady forest, crevices in rock faces, and also grow in arctic and alpine tundra, saline mangrove swamps, semiarid deserts and on coastal rocks. The greatest number of fern species can be found in the tropics of both hemispheres. It was estimated that about 10500-11300 of the fern species have been described and 1165 species were recorded in the tropical rain forest of Malaysia. This lecture discusses the morphological diversity, anatomy and cytology of Malaysian rain forest ferns. Selected research works on morphology, anatomy and cytology of these ferns are reviewed. The economic importance of ferns as food, medicine, fibre, craft, fuel and building materials is also discussed. In addition, a number of comprehensive studies on the chemistry and biological activities in ferns are also reviewed. Apart from exploitation of fern taxa for their significant scientific documentation and economic value, the awareness on their conservation status is also emphasized.

INTRODUCTION

Ferns

Ferns are seedless vascular plants that are grouped together with fern allies in the plant kingdom called the Pteridophyta. They have stems, fronds, pinnae and roots like other vascular plants. They differ from seed plants (gymnosperms and flowering plants) in that they do not have either seeds or flowers, as they reproduce via spores. They have many features similar to mosses and algae but are usually differentiated from these simpler plants as they have xylem and phloem for the conduction of water and food materials. Like gimnosperms and flowering plants, ferns have life-cycles which are referred to as alternation generations, characterized by a gametophyte (sexual) phase and a sporophyte (asexual) phase. The male gametes, produced in numbers from the antheridia, are known as antherozoids, since they are flagellated and are able to swim in water, while the female gametes (egg cells) are non-motile and are borne singly in flask-shaped archegonia. Fusion between an egg cell and an antherozoid results in the formation of a zygote. The zygote develops by mitotic divisions into the sporophyte which is diploid (**Figure 1**).

A number of non-motile spores are then released from the sporophyte. The life-cycle is then completed when these spores germinate and grow, by mitotic divisions, into haploid gametophytes. In mosses, liverworts and algae, the dominant phase in the life-cycle is the gametophyte, as the sporophyte is dependent on the gametophyte for nutrition. By contrast, in ferns the sporophyte is the dominant generation (**Figure 2A**), as it becomes independent of the gametophyte (prothallus) and grows to a much greater size (**Figure 2B**).

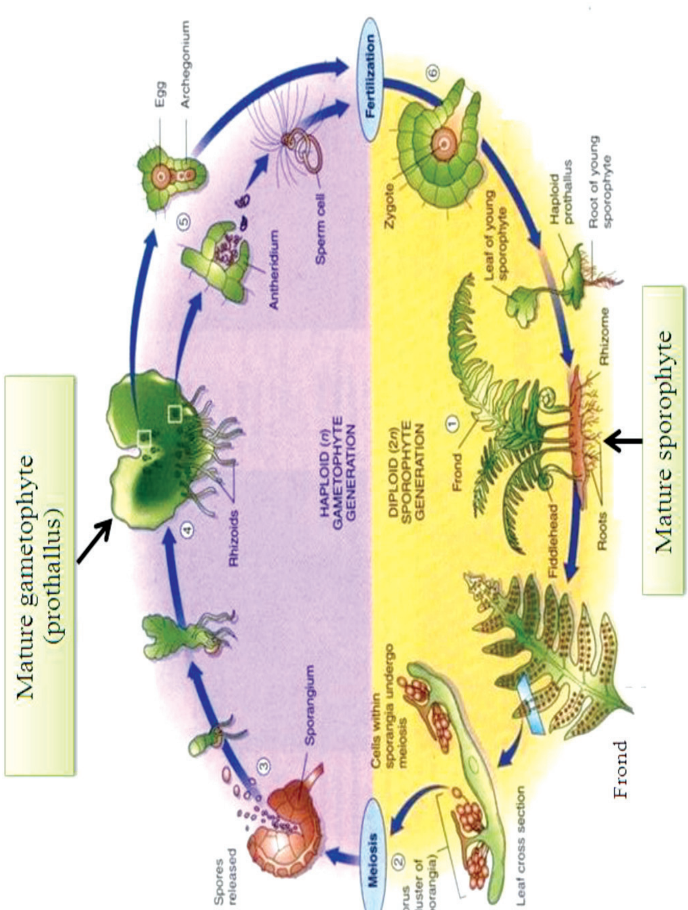


Figure 1 Fern lifecycle (Source: Mader, 2007)

Along with its greater size is a much greater degree of morphological anatomical complexity as the sporophyte is organized into stems, leaves and roots (Sporne, 1975; Mader, 2007).

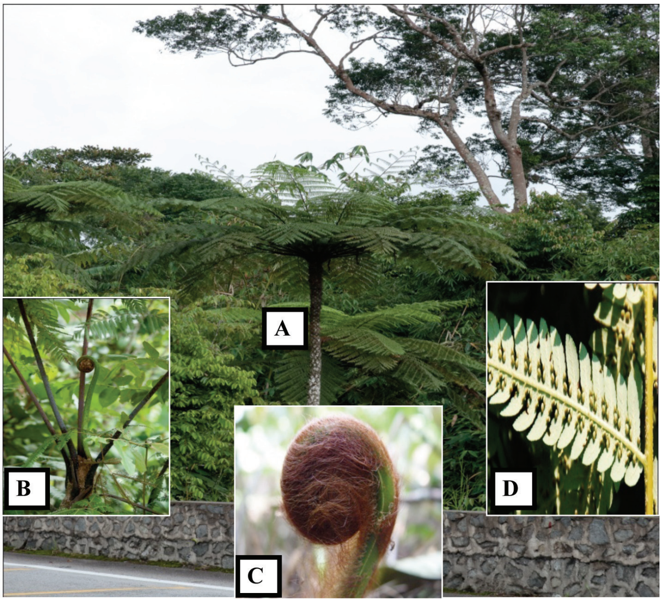


Figure 2A Cibotium barometz (penawar jambi). A. Sporophyte; B. Circinnate vernation; C. Close-up of circinnate vernation; D. Fertile frond (Photographed by A. Kahar)

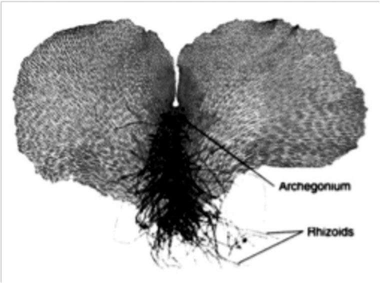
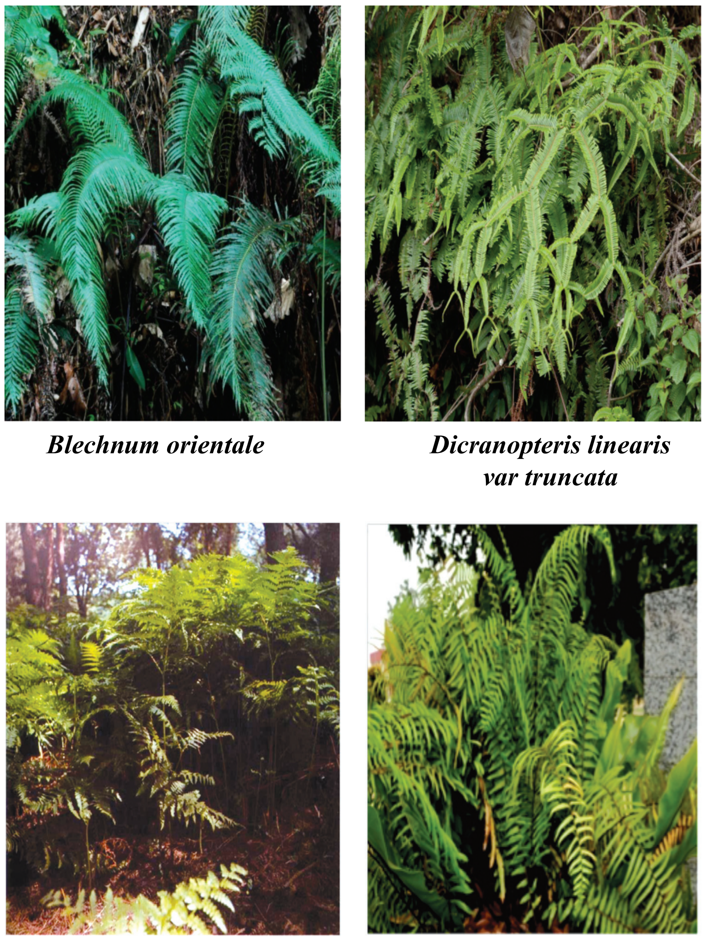


Figure 2B Fern prothallus (Source: Mader, 2007).

Origin, Distribution and Ecology

Ferns first appear in the fossil records of the Carboniferous but many of the current families and species did not appear until roughly the late Cretaceous (after flowering plants came to dominate many environments). The origin of ferns is uncertain but it is believed that they are more closely related to algae rather than mosses and may have originated from them. The highest diversity of fern species is found at lower altitudes. They are most common in the understory of humid temperate and tropical forests. However, they are widely distributed, and also grow in the arctic and alpine tundra, saline mangrove swamps, semiarid deserts and on coastal rocks swept by salt spray. Ferns can provide the bulk of biomass in some tropical forests and dominate the understories of some temperate conifer forests (Rost et al., 2006). Only a relatively small number is adapted to dry and sunny conditions by having either reduced surfaces or a covering of hairs or scales to prevent loss of moisture. The greatest number of fern species is found in the tropics of both hemispheres (Jahns, 1983). At present, 10500 to 11300 species have been described worldwide, a number that is expected to increase to about 12000 to 15000 species. In South East Asia around 4400 species of ferns are known and 1165 species were recorded from the tropical rain forest of Malaysia (Roos, 1996; Parris and Latiff, 1997). Some of the fern species have a relatively small range and some are even limited to a single mountain. Less than 10% of the species have very wide to cosmopolitan ranges, while the bracken (*Pteridium aquilinum*) is ranked among the top ten most abundant vascular plants of the world (Roos, 1996). Most ferns are found on the forest floor (terrestrial) but some fern species grow on the trunks and branches of tress, and these are called epiphytes (Holttum, 1954). The common ferns of the open countryside which we see every day are *Dicranopteris linearis* (Resam) and

Pteridium aquilinum (bracken). Resam form a tangled thicket which is extremely difficult to cut through (**Figure 3**).



R. Jaman

Blechnum orientale

A. Kahar

Dicranopteris linearis var truncata

A. Kahar

Pteridium aquilinum

A.H. Moin

Nephrolepis biserrata

Figure 3 Terrestrial ferns

Resam smothers the soil completely and hardly anything can grow through it. However it protects the soil from erosion and its roots do not penetrate deeply. Bracken usually forms thickets which are less dense as compared to Resam. It grows in lighter soil and its rhizome is embedded much deeper in the earth. The commonest sun-ferns, *Blechnum orientale* (paku merah) and *Pityrogramma calomelanos* (silver fern) have a rootstock which is more or less creeping and though they do not form thickets like Resam their fronds may grow very abundantly over an area of ground. A very remarkable group of sun-ferns is provided by the genus *Nephrolepis.* They produce tufts of leaves like the solitary ferns and very slender creeping runners grow out from these turfs, each of which may produce a new tuft of fronds some distance from the original one.

Epiphytes only live on the surface of the bark and have to gather all its water through its roots. They do not harm the tree, except that a large mass of epiphytes may have a smothering effect or may even break a branch with its weight. Epiphyte ferns are quite cut off from the ground. Their roots find protection in various ways and often grow along with mosses. Over time the roots usually form a mat and gradually collect humus, which absorbs moisture during rain and from the night dew. Some of them, like the *Asplenium nidus* (birds-nest fern), *Asplenium phyllitidis, Platycerium* (stag's-horn fern) and *Drynaria,* have special methods of accumulating humus. *A. nidus* has a great mass of roots where the humus caught in the nest absorbs a large quantity of water during rain. *Platycerium* has a slightly different method of collecting humus. It has very broad erect fronds which together form a basket which catches dead leaves like the nest of the *A. nidus* (**Figure 4A**). It also has fronds of another kind which hang down and bear the sporangia. When the basket-leaves are old, they wither and curl inwards, holding all the debris they have caught, pressing it against the previous leaves which behaved in the same way. At the same time a new set of basket-leaves develop. In this way the fern completely encloses its catch of debris, and the roots grow up into it between the dead-fronds of the fern. These fronds, thus, not only protect the humus but also protect their roots against drying winds. The whole arrangement is thus more efficient than that of the *Asplenium.* Another common epiphyte which protects its roots and catches humus by means of special leaves, but on a much smaller scale, is the *Drynaria,* the Oak-leaf fern. It has two kinds of fronds. One grows long and behaves like ordinary leaves, and soon turn brown while the latter fronds cover and protect the roots and catch a certain amount of debris which will provide both food and water-absorbing material for the roots.

Some relatives of *Drynaria* have both kinds of leaves combined into one. These ferns store water in a spongy mass of roots and debris. The fairly common ferns *Antrophyum reticulatum* and *A. brooker,* have no special arrangement for this, though most of them have very many hairy roots which spread into a mat and collect some debris. They rely more on internal storage of water. Both of these ferns live on trees or rocks near ground in shady forests (**Figure 4B**).

Most epiphytes in exposed places have more or less fleshy leaves, the commonest and most striking being the *Davallia, Pyrrosia* and *Drymoglossum* species. A section through one of these leaves shows a fairly thick layer of large cells which contain little water. Other ferns, such as *Davallodes, Lemmaphyllum* and *Loxogramme,* have thick fleshy rhizomes which can store water (**Figure 4C**).

Climbing ferns have a long slender rhizome, which climbs a tree as soon as it meets one. They often start life on the ground and trail along until they come to a tree; or sometimes they may start just at the base of the trunk and have roots in the ground. The most common climbing ferns are the *Stenochlaena palustris* and *Lygodium* (**Figure 5**).

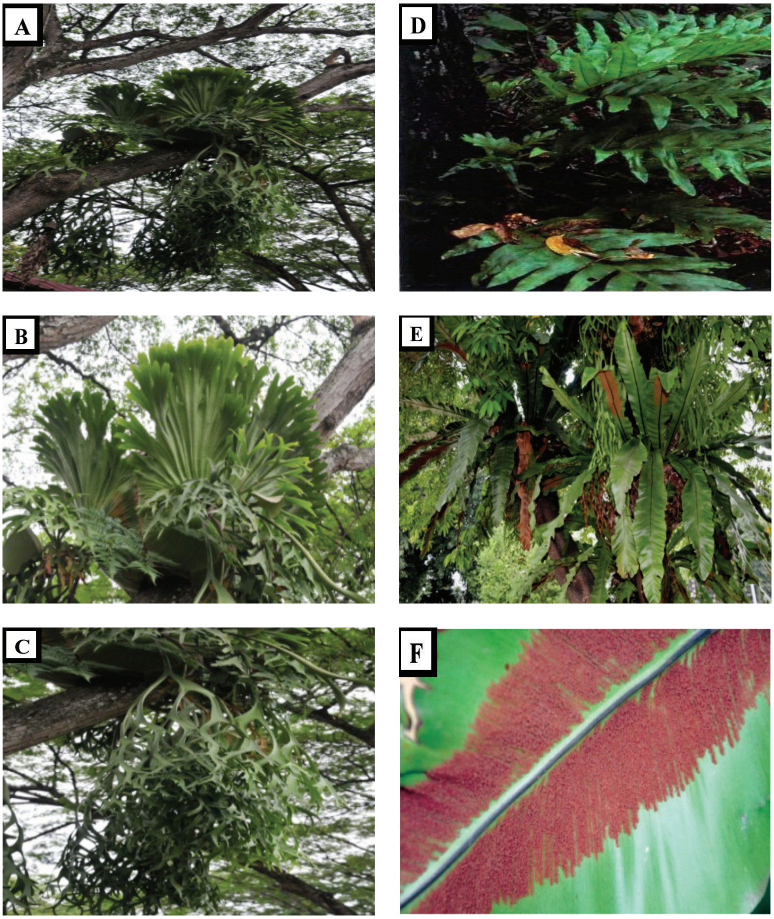


Figure 4A Epiphytic ferns with modified fronds. A. *Platycerium coronarium*; B. Sterile frond; C. Fertile frond; D. *Drynaria quercifolia*; E. *Asplenium nidus*; F. Fertile frond (Photographed by R. Jaman and A. H. Moin)

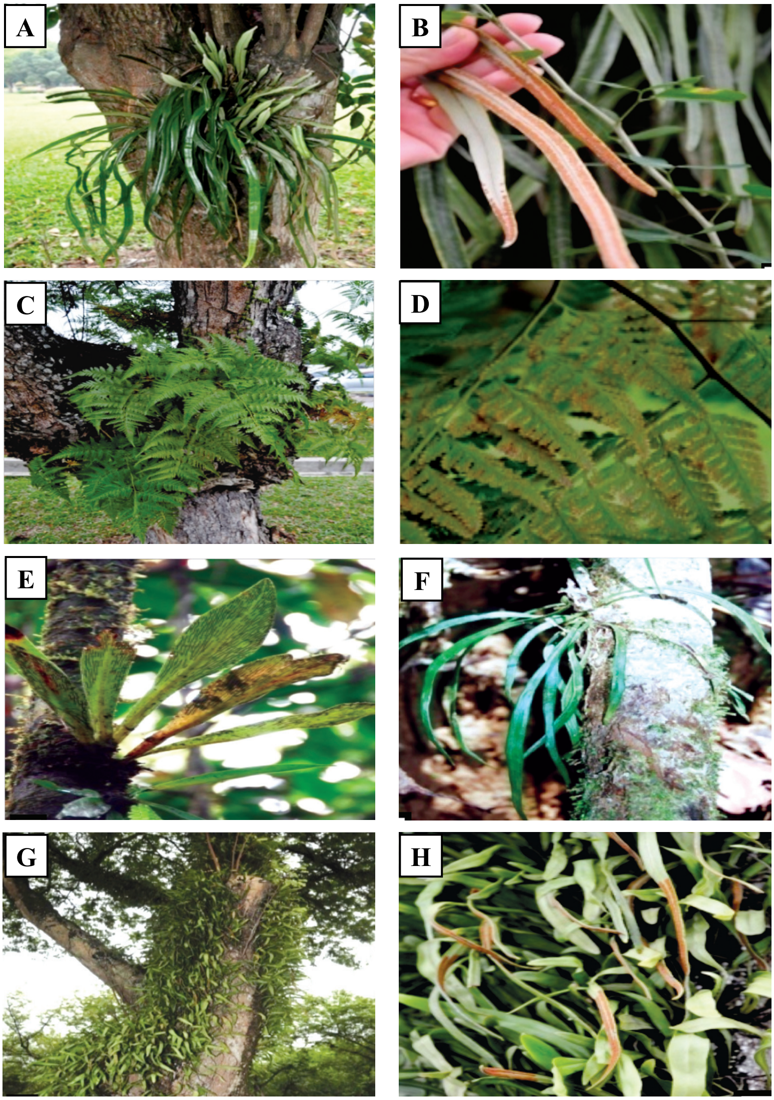


Figure 4B Epiphytic ferns. A. *Pyrosia longifolia;* B. Fertile frond; C. *Davallia denticulata;* D. Fertile frond; E. *Antrophyum reticulatum;* F. *Anthrophyum brooker;* G. *Pyrrosia varia;* H. Fertile frond (Photographed by A. H. Moin)

Lemmaphyllum accedens

Davallodes borneensis

Loxogramme antrophyoides

Loxogramme scolopendrioides

Figure 4C Epiphytic ferns with fleshy rhizome (Photographed by R. Jaman)

Figure 5 Climbing ferns. A. *Lygodium circinnatum;* B. Frond, C. *Stenochlaena palustris;* D. Fertile frond (Photographed by A. Kahar and Rusea Go)

There are some ferns that only grow on rocks and some that only grow along rocky river banks (lithophytes), such as the *Bolbitis diversifolia, Dipteris lobbiana, Trichomanes sublimbatum* and *Lindsaya orbiculata* var. *orbiculata* (**Figure 6**).


R. Jaman

Lindsaya orbiculata* var. *orbiculata


Ho Cher Wei

Trichomanes sublimbatum


R. Jaman

Dipteris lobbiana


R. Jaman

Phyllitidis scolopendrium

Figure 6 Rocky ferns

Mangrove ferns such as the *Acrostichum speciosum* is common in the mud brackish inlet estuaries and large tidal rivers of the tropics. Aquatic ferns such as *Ceratopteris thalictroides, Azolla,* *Salvinia* (**Figure 7**) and *Marsilea* have adapted their whole life-cycle around the presence of permanent fresh water (Holttum, 1954; Piggot, 1988).

Figure 7 Aquatic fern; *Salvinia molesta* (Photographed by Rusea Go)

A few fern species such as the *Pteridium aquilinum* (bracken), *Lygodium* (climbing fern) and *Salvinia* (water fern) are weeds. They smother other vegetation, clog waterways and poison livestock (Rost et al., 2006).

Fern Collectors

Peninsular Malaysia is one of areas with the best collections of ferns in the Malesian region, with the earliest collection dating from *c.* 1821. One of the earliest fern collectors was G. Finlayson, who collected ferns from Penang between December 1821 and January 1822. His fern herbariums are deposited at Kew, and duplicates distributed to Berlin, Brisbane, Cambridge, Floence and Leiden.

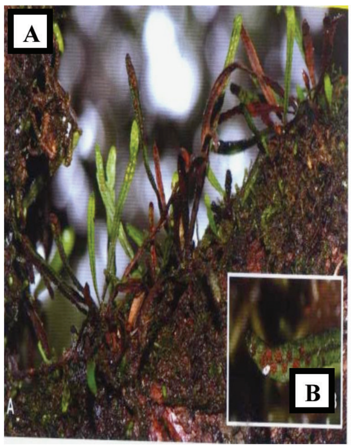
H.N. Ridley, the first Director of the Botanic Gardens, Singapore (1880-1912), collected ferns extensively throughout Peninsular Malaysia and Singapore. J.J.M. de Morgan collected some ferns from Penang and Perak in 1844. G.F. Hose was a collector of ferns while he was in Melaka (1868-1873) and Singapore (1871-1881). His collections are in Edinburgh and Kew. C.G. Matthew, made a small but valuable collection of ferns in 1904 and from 1911 to 1913, particularly from hills accessible from the west coast. His collections are in Edinburgh, Kew and Bogor. R.E. Holttum collected ferns from the time he became Assistant Director in the Botanic gardens, Singapore in 1922 until he retired as Professor of Botany at the University of Malaya in Singapore in 1954. He collected ferns from many mountains and a few from limestone outcrops. His collections are deposited in Singapore, the Natural History Museum, London and Kew and local herbaria. B. Molesworth Allen collected ferns between 1948 and 1963, totaling about 3,300 specimens, mostly in Perak and the Cameron Higlands, Pahang. Most of her collections are in Singapore, Kew, Natural History Museum, London and Forest Research Institute Malaysia.

Botanical collections up to the 1970s have been well documented by Burkill (1927) and Steenis-Kruseman (1950, 1958, 1974). Many collectors are little known because they did not publish their findings, for example, E.A. Turnau (1961-1969), Abdul Samat (1961-1969) and G.B. Evans (1966) and all staff of University Malaya, where their collections are mainly deposited (Parris and Kiew, 2010).

F.L. Dunn made a small collection of ferns from Gunung Jerai, Kedah in 1967 (Dunn, 1967). A.G. Piggot collected ferns between 1970 and 1975. Her collections are deposited at Kew with a few specimens in Singapore. She focused mainly on two mountains, Gunung Telapak Berok, Negeri Sembilan (Piggot, 1977, 1982) and Gunung Ulu Kali, Pahang, as well as the lowlands in Negeri Sembilan.

Since the 1970s, Universiti Kebangsaan Malaysia has become the focus of pteridophyte research with the most comprehensive fern and lycophyte herbarium in Malaysia housing about 25,000 species, mainly collected by Abdul Aziz Bidin, Haja Maideen Kadeer Maideen and Razali Jaman. Abdul Aziz Bidin also established a Fernetum for germplasm and cytological research. Moreover the discovery of new taxa and records from specific areas have also been documented by many other collectors: from Gunung Ulu Kali, Pahang - *Ctenopherella khaoluangensis* (Parris, 1986); *Ptisana pellucida* (Marattiaceae) (Maideen et al., 2002), *Oreogrammitis malayensis* (Grammitidaceae) from Taman Negara, Pahang (Parris, 2007); - *Osmunda valechii* (Osmundaceae) (Aziz Bidin, 1984), *Tectaria translucens* (Parris and Edwards, 1988); from Endau-Rompin, Johor - *Schizaea fistula* (Schizaeaceae) (Kiew et al., 1987); from the Royal Belum State Park, Perak - *Asplenium grevillei* (Edward et al., 1995); from Wang Kelian, Perlis - *Tectaria shahidaniana* (**Figure 8**); and from Gua Cha, Kelantan - *Tectaria guachana* (Rusea Go *et al.*, 2004).

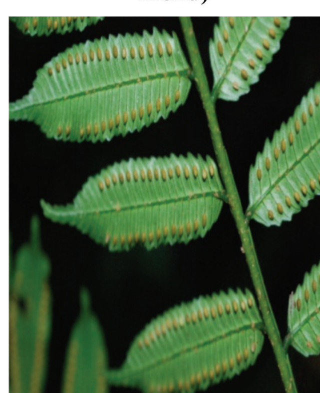
Chin (1977) documented botanists who specifically collected ferns from limestones. This includes C.E. Carr (1928-1930) in central Pahang; R.E. Holttum in Batu Caves, Selangor (1922) and Langkawi (1925); B. Molesworth Allen (1950-1960) in Perak and G. Keriang, Kedah; C.I. Phang (1960) in Bukit Anak Takun; UNESCO Expedition to Kelantan limestone hills (1962); Abdul Samat (1961-1969) in Bukit Takun and Anak Bukit Takun and Langkawi; G.B. Evans (1966) in Ipoh Temple, Perak, Bukit Takun, Selangor; (1968) and Batu Caves, Selangor. However, these limestone collections resulted in only a few new records or species, notably *Doryopteris* *alleniae* collected by Molesworth Allen and *Drynaria bonii* (Polypodiaceae), a new record from Langkawi, reported by Chin (Parris and Kiew, 2010).



Oreogrammitis malayensis
(A. Sporophyte, B. Fertile frond)

Osmunda vachelli
(C. Sporophyte, D. Fertile frond)

***Tectaria shahidaniana* (Sporophyte)**



Ptisana pellucida
(Fertile frond)

Figure 8 New records and new species of Peninsular Malaysia ferns (Source: Bidin, 1984; Maideen et al., 2002; Rusea Go et al., 2004; Parris, 2007)

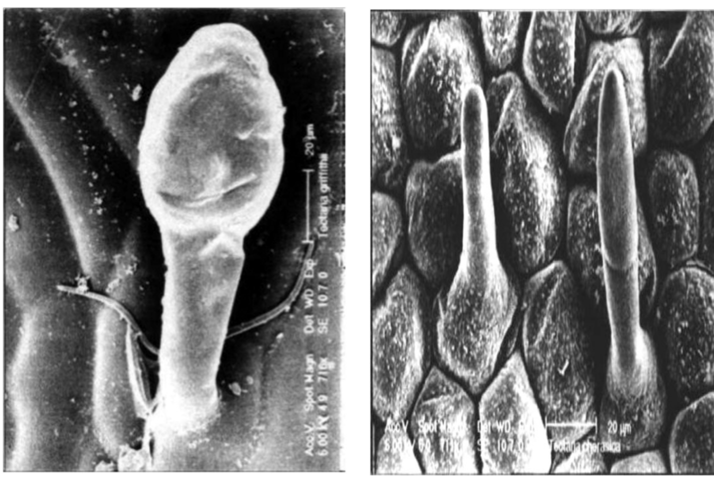
Morphological Diversity of Ferns

(a) Rhizome and Fronds

The plants we recognize as ferns are the sexual generation and are known as sporophytes, i.e. they produce spores. A distinctive characteristic of the sporophyte generation of ferns is the arrangement of the young leaf (frond) in the bud. The young frond of the fern is coiled in a manner known as circinnate vernation (**Figure 9**) or hooked like a sheperd's crook (known as non-circinate vernation). This is an excellent guide to identifying ferns in the field. During development, the young leaf elongates and begins to uncoil and the leaf-blade expands to produce the mature frond.

Figure 9 A. Young sporophyte of *Blechnum orientale;* B. Naked circinnate vernation of *Blechnum orientale;* C. Scaly circinnate vernation of *Blechnum damahurianum* (Photographed by R. Jaman)

Fern rhizomes vary from short and thick to long, creeping and wiry. In some species of ferns they are erect and in tree ferns they form a characteristic woody trunk. The young part of the stipe and coiled fronds of ferns are protected by dry structures which may be scales, bristles or hairs (**Figure 10A**). They consist of an arrangement of flat cells. The hairs may be glandular or non-glandular (Johnson, 1977; Piggot, 1988). The scales may be linear, lanceolate, oblong, peltate and flabellate and such descriptions are of taxonomic significance (**Figure 10B**).



Glandular hair Non-glandular hair

Figure 10A Hairs of the stipe (Source: Rusea Go et al., 2004)

Some fern leaves are dichotomously branched or lobed. A more common organization is the simple frond, pinnate, bipinnately or tripinnately compound leaf (**Figure 11**). The leaflets are called pinnae in ferns, and the leaves are called fronds.

The young fronds of many species of ferns are often a different colour to the mature fronds, usually shades of pink, red or purple. For example *Blechnum orientale, B. finlaysonianum* and *B. indicum* commonly have bright pink or red new fronds. *Stenochlaena palustris* also have similar bright colourations in their new fronds.

Young fronds of *Woodwardia auriculata* often have tawny or orange tones (Holttum, 1954).

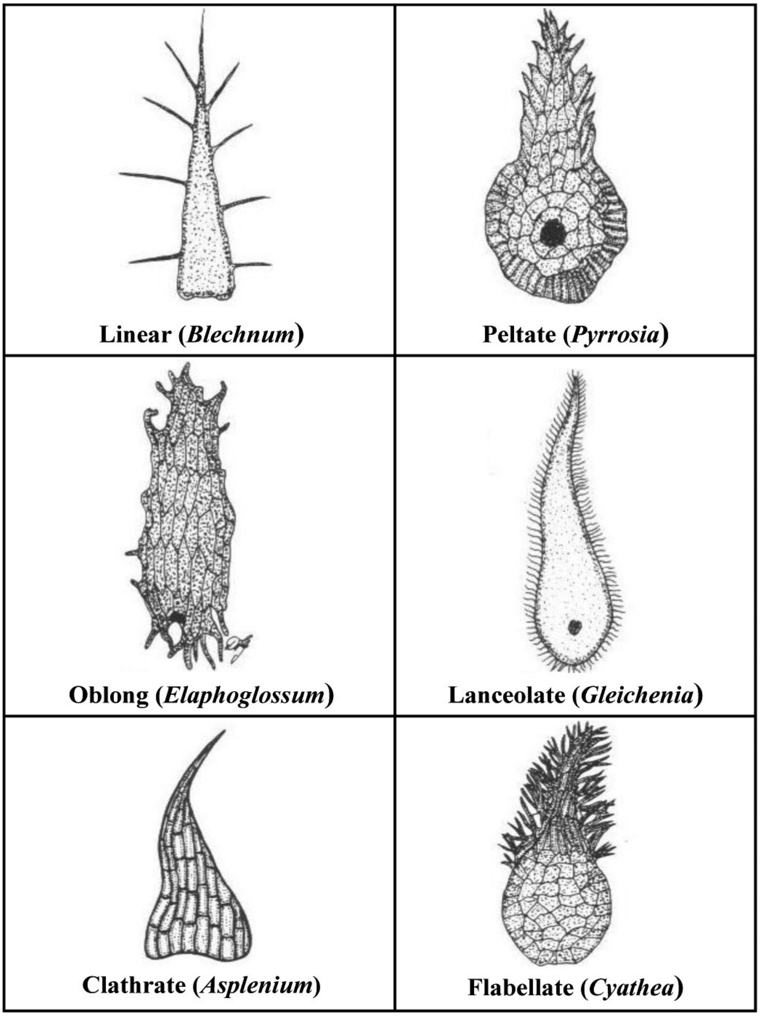


Figure 10B Scales of the stipe (Source: Holttum, 1954; Umi Kalsom, 2002)

R. Jaman

Simple
(*Microsorium punctatum*)

R. Jaman

Palmate
(*Matonia pectinata*)

R. Jaman

Pinnate
(*Microlepia strigosa*)

Rusea Go

Tripinnate
(*Odontosoria chineensis*)

Figure 11 Shape and arrangement of the fronds

A number of ferns which grow in sunny habitats have colourful waxy deposits on the new fronds and on the underside of mature fronds. These secretions make the fronds appear as if they have been dusted with flour. They are thus termed farinose and the secretions are called farina. The secretions are produced by specialized glands on the fronds and they act as a moisture conserving mechanism. They are white or silvery, yellow or deep gold, or roseate pink. Secretions of this type are particularly prominent on various species of *Pityrogramma,* and they give rise to such common names as Gold Fern or Silver Fern (**Figure 12**). They are also commonly found in the fern *Cheilanthes tenuifolia.*

R. Jaman

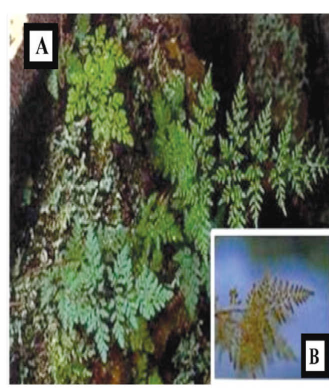
Red fronds
(*Blechnum orientale*)

R. Jaman

Variegated fronds
(*Pteris argyraea*)

R. Jaman

Waxy silver powder
(*Pityrogramma calomelanos*)



A. Kahar

Waxy gold powder
(*Cheilanthes tenuifolia;*
A. Sporophyte, B. Fertile frond)

Figure 12 Young fronds

Variegated ferns are not prominent in nature, probably because the reduced chlorophyll levels weaken their competitiveness. *Pteris ensiformis, P. cretica and P. arygyraea* are perhaps the most striking examples of variegated ferns, with a prominent white stripe down the centre of each pinna (Johnson, 1977). The shape, size and colour of these structures may be useful or even important diagnostic features.

(b) Sorus and Spores

Ferns do not have flowers; they reproduce through tiny spores which are carried in sporangia which are clustered in a group known as a sorus (**Figure 13 and 14**).

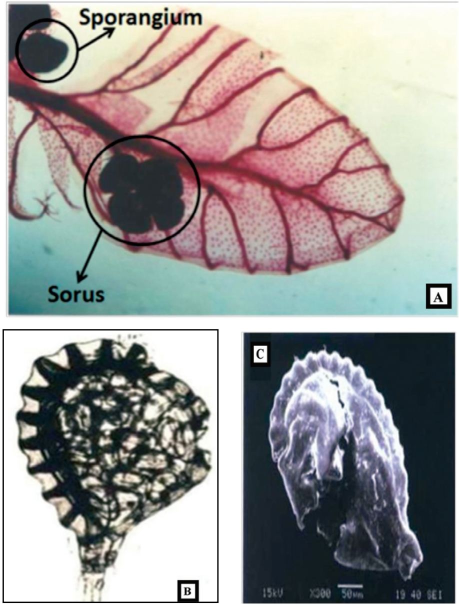


Figure 13 A. Pinna of *Gleichenia longisimma* showing the sporangium and sorus. B. Sporangium under light microscope, C. Sporangium of *Pteris asperula* under SEM (Source: Umi Kalsom, 1982; Rozilawati Shahari, 2008)

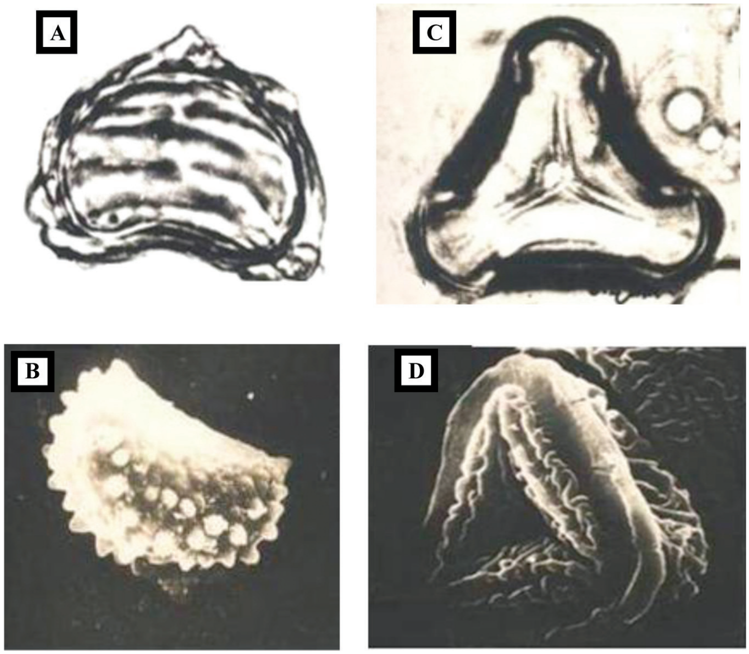


Figure 14 Shape of fern spores. Monolete spore: A. View under light microscope, B. View under SEM. Trilete spore: C. View under light microscope, D. View under SEM (Source: Umi Kalsom, 1982)

A group of sorus is termed as sori. Sori are commonly found on the underside of fronds but in some species they occur on the frond margin, on the midrib or along the vein (**Figure 15**).

Sori may be naked or protected by a thin, often membranous, flat structure known as the indusium (**Figure 16**). There are various types of indusium shapes, reniform, cup-shaped, shield-shaped or trumpet-shaped (Holttum, 1954; Hor Cher Wei, 2005; Jaman and Umi Kalsom, 2010a).

Some sori occur under marginal flaps (false indusia) or in marginal pockets (Rozilawati Shahari, 2009). Some sori are borne terminally on lateral branchlets, so the broad, photosynthetic leaflets are sterile (Jaman and Umi Kalsom, 2010b). The shape, size and location of sori are important diagnostic features for identifying ferns in the field.

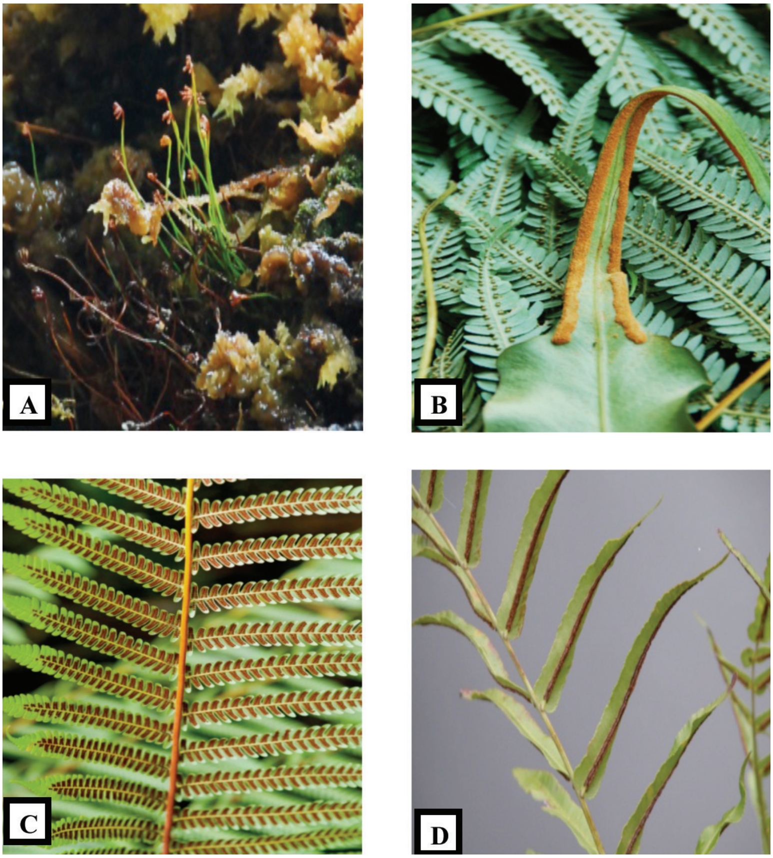


Figure 15 Fern sori: Terminal sorus (A. *Schizaea malaccana*); sorus along the margin (B. *Belvisia neoguineensis*); sorus on underside of the fronds (C. *Cyathea contaminans*); sorus along the midvein (D. *Blechnum indicum*) (Photographed by R. Jaman)

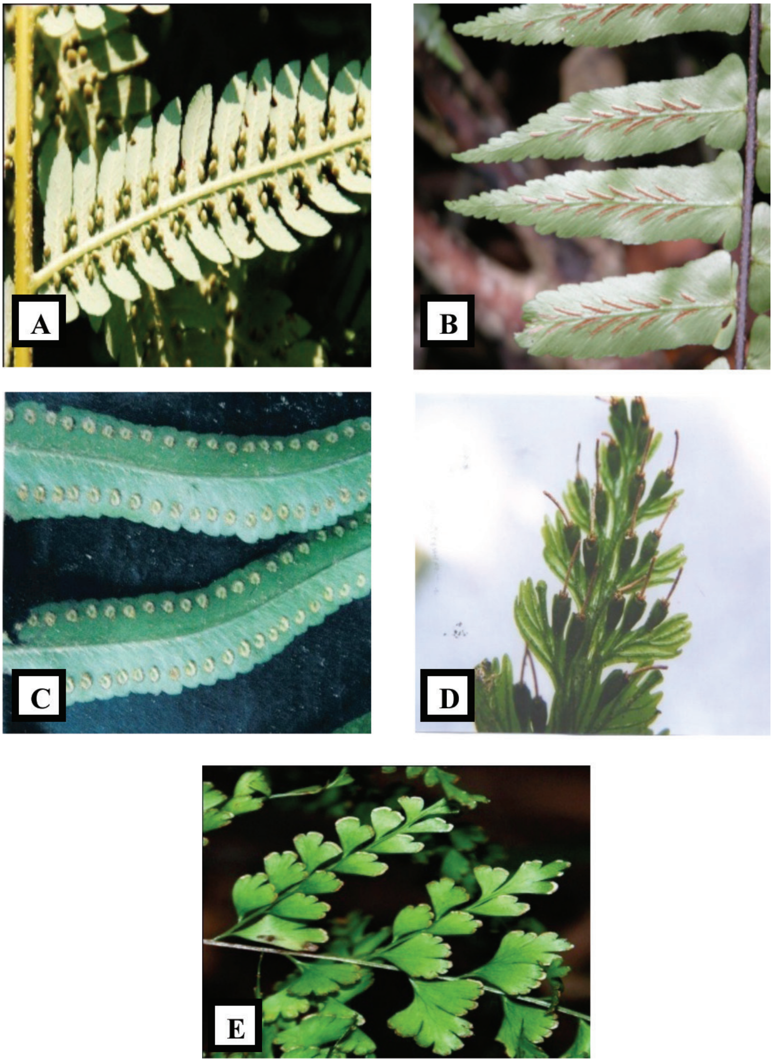


Figure 16 Indusium. A. Cup-shaped indusium (*Cibotium barometz*); B. Indusium along the vein (*Asplenium longissimum*); C. Reniform indusium (*Nephrolepis biserrata*); D. Trumpet indusium (*Trichomanes obscurum*); E. False indusium (*Lindsaea orbiculata* var. *orbiculata*) (Photographed by R. Jaman)

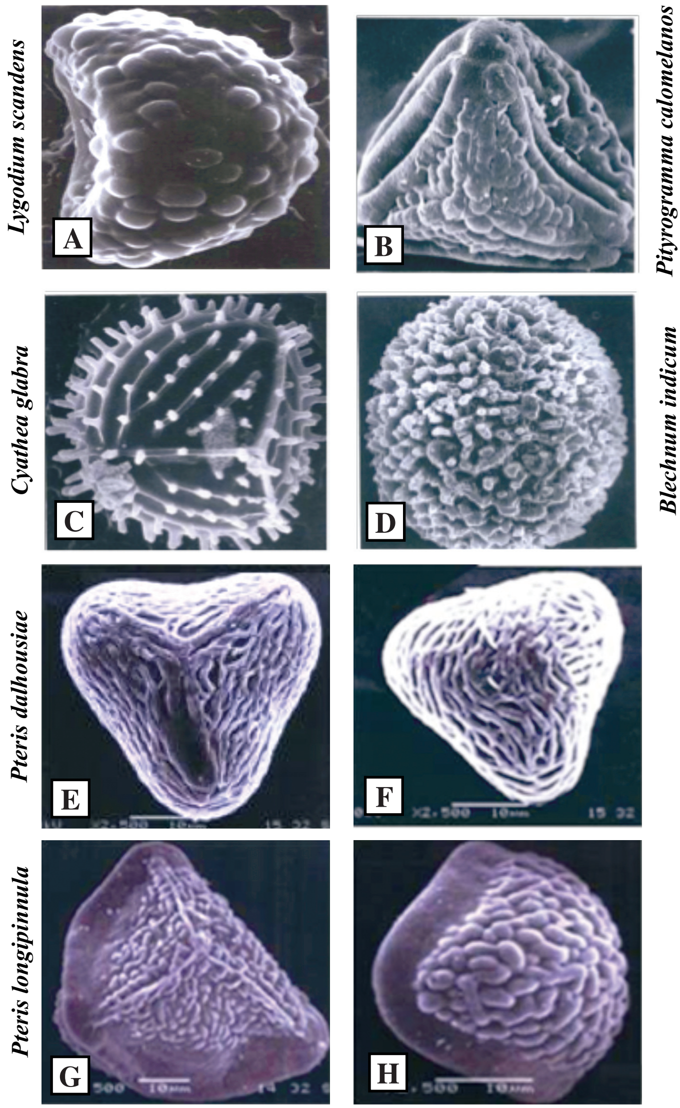


Figure 17 Spore surface ornamentation. A-B. Regulate, C-D. Dentate, E. Costate; proximal view surface. F. Costate; distal view, G. Verrucate; proximal view, H. Verrucate; distal view (Source: Umi Kalsom, 1982; Rozilawati Shahari, 2008)

The fern spores are monolete or trilete in shape (**Figure 17**). The size and surface ornamentation varies from species to species (Umi Kalsom and Jones, 1984). Monolete spores with irregular echinate, fimbriate wings and tubercles echinate folds were observed in most species of *Tectaria,* whereas spores with verrucose-rugulate exine were observed in most species of *Histiopteris* (Rusea, 1997; Faridah Hanum *et al.,* 2008).

Trilete spores with regulate, dentate, verrucate and costate ornamentation were observed in *Schizaea* (Bidin and Aryati, 1996), *Pteris* (Bidin and Aryati, 1997; Rozilawati Shahari, 2008), *Trichipteris* (Gastony, 1979), *Lygodium, Pityrogramma, Blechnum* and *Cythea* (Umi Kalsom, 1982).

Observations of Ferns

Botanists have collected ferns and made significant contributions to the study of fern morphology, anatomy, ecology and cytology. The outstanding pteridologist in Peninsular Malaysia and Singapore, R. E. Holttum, described his morphological and anatomical observations of ferns in his book, *Revised flora of Malaya, 2* (Holttum, 1954). Molesworth Allen (1959a, 1959b) contributed interesting observations of ferns' succession in montane vegetation and areas around stations on mountain summits. Piggot's (1988) *Ferns of Malaysia in Colour,* documented the distribution, photographs and identification of ferns for those who prefer to work from pictures rather than text.

Detailed anatomical observations of ferns have been made by several others including Umi Kalsom (1992), Chin (2006) and Nor-Ezzawanis (2009). The anatomical data obtained have been useful in improving existing fern classification and phylogeny. Umi Kalsom (1992) observed the structure of vascular patterns in the stipe and rachises of Aspleniaceae and Athyriaceae. She found that the vascular patterns in the species examined do not appear to provide useful characters for distinguishing between species. However, they give valuable taxonomic information at the generic level. In Athyriaceae, *Deparia* can be distinguished from *Athyrium* and *Diplazium* as the stipe of the *Deparia* shows three xylem strands which unite in the rachis to form a V-shaped strand. The different number of xylem strands in *Deparia* as compared to the usual binary type in *Diplazium* and *Athyrium* seems to support their taxonomic segregation. Most species of *Athyrium* and *Diplazium* have double xylem strands in their stipe where the two xylem strands in the stipe unite in the rachis to form a single U-shaped strand.

Asplenium and Athyriaceae had previously been grouped together in a single family, Aspleniaceae (Ching, 1940), or the subfamily, Asplenoideae. From the results of anatomical data, it is possible to recognize that these two fern groups are markedly distinct from each other. The Aspleniaceae (15 species) are characterized by two C-shaped xylem strands of the stipe fusing in the rachis to form an X-shaped strand. On the other hand, in the Athyriaceae (12 *Diplazium,* 13 *Athyrium* and *Deparia japonica*) the two 'ear-like' xylem strands at the base fuse into U- or V-shaped strands. These differences are important diagnostic criteria to differentiate these ferns, which often have confusingly similar pinnae arrangements. Furthermore, Athyriaceae differs from Aspleniaceae in having linear scales along the rhizome and stipe, horse-shoe or J-shaped indusium and chromosome numbers of n= 41, 82, 123 and 200. In constrast, Aspleniaceae possess clathrate scales, narrow indusium attached along the vein, (Holttum, 1954) and chromosome numbers of n= 36, and 70-72 (Manton and Sledge, 1954).

Chin Lea Yen (2006) observed two types of vascular bundles in Gleicheniaceae. She stated that the genera of Gleicheniaceae have two types of vascular bundles in the stipes. The C-shaped vascular pattern is observed in the stipes of *Dicranopteris, Diplopterygium* and *Sticherus,* whereas circular-shaped vascular bundle is only observed in the stipe of *Gleichenia* (**Figure 18**). Nor-Ezzawanis (2009) studied the construction of the stele of the rhizome of Grammitidaceae and observed two types of stele, that is, solenostele or dictyostele. She also stated that the arrangement of vascular structure in the rhizome can be used to distinguish the genera within Grammitidaceae.

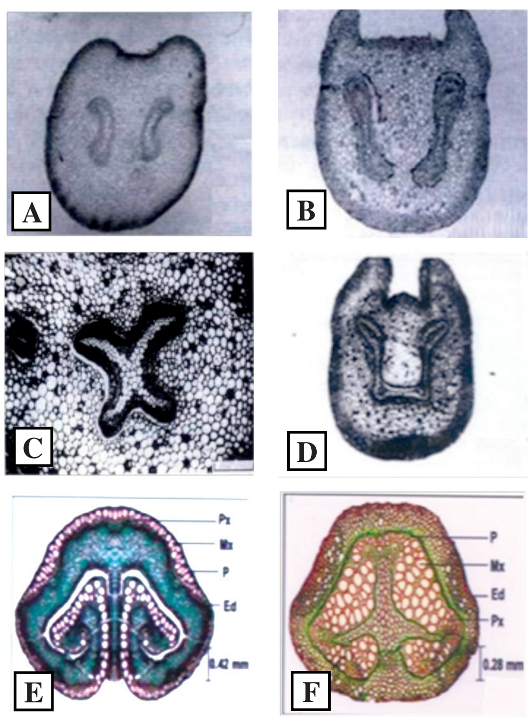


Figure 18 Cross section of the stipe and rachis in the ferns. A. Stipe of Aspleniaceae; B. Stipe of Athyriaceae; C. Rachis of Aspleniaceae; D. Rachis of Athyriaceae; E. Stipe of *Dicranopteris*; F. Stipe of *Gleichenia* (Source: Umi Kalsom, 1992; Chin Lea Yin, 2006)

There are few published accounts of the ecology and cytology of Malaysian ferns. Umi Kalsom and Jones (1984) studied the spores and sporangia morphology and the habitat of ferns from Peninsular Malaysia and Mount Kinabalu. Results of their study have shown that the morphology of spores and sporangia from various types of habitat are similar. Gay et al. (1994) carried out detailed observations on the ecology of the ant-fern, *Lecanopteris* (Polypodiaceae), with a view to understanding the distribution of species and characteristics of the host tree, including bark type and the vegetation and soil type in which the host tree grew. Bidin and Rusea Go (1995) studied the chromosome number of the *Tectaria* and found eight tetraploid species of *Tectaria* with chromosome numbers of n=78 and one diploid species with chromosome number of n=39. They also suggested that the genus *Tectaria* has two base numbers, n=39 and n=40 (**Figure 19**).

Figure 19 Chromosome structure of *Tectaria*. A. Chromosome; a. Habit (Source: Bidin and Rusea Go, 1995)

Bidin (2000) summarized the cytological information available for 138 taxa or cytotypes of Malaysian ferns, representing about 12% of the fern flora. Polyploidy proved to be lower (42%) than is encountered in temperate regions (52-54%) and only one octoploid, *Syngramma coriacea* (Pteridaceae) (n=116), is known to be from Malaysia.

Economic Uses

Man has been using plants as a source of food, medicine and many other necessities of life since time immemorial. Even now, primitive tribal societies depend largely on the plant life in their surroundings. Though the economic and medicinal values of flowering plants have been investigated, ferns have unfortunately been ignored. Ferns make an important contribution to the earth's plant diversity. Being the second largest group of vascular plants, they form a significant, dominant component of many plant communities. Ferns are found to provide food, medicine, fibre, craft, fuel and building material and decoration (Croft, 1985; Benjamin and Manickam, 2007).

Food

(a) Starch

With very few exceptions ferns have not been widely used as a source of food. The fern's stems, rhizomes, leaves, young fronds and shoots and some whole plants are used for food. Several fern species store starch as a reserve, especially in the rhizome. In the past these ferns served as supplementary food sources or were used to produce alcohol. However, due to the low quantity and quality of the starch, this habit has largely been abandoned. Species treated that have served as source of starch include *Angiopteris evecta, Cibotium barometz* and *Pteridium aquilinum* (Norton, 1979; Bidin, 1985; Jaman and Umi Kalsom, 2010c). Further, in Sicily, ferns are said to contribute to increased milk production when fed to cows (Mannar Mannan et al., 2008).

(b) Vegetables

Many fern species have been recognized as having young leaves that can be eaten as vegetable. All of these species are harvested from the wild, and can be seen covering whole market stalls. Some have an exquisite taste and are sold as a delicacy. Especially young leaves that are still curled or partly curled are consumed. When the leaves mature, concentrations of certain chemical constituents such as alkoloids damage the taste and in some species may eventually impose adverse health effects upon the consumer. The older leaves also become unpalatable as a result of the build-up of structural material (Burkill, 1966).

Figure 20 Vegetable ferns. A. *Stenochlaena palustris*; B. *Helminthostachys zeylanica*; C. *Diplazium esculentum* (sporophyte); D. Young shoot

In the Old World tropics ferns are widely used in traditional societies as a source of vegetables in the diet of village people. Up to 16 species of ferns are eaten by traditional communities in East Malaysia and Peninsular Malaysia, mostly gathered from the forests (Jaman and Umi Kalsom, 2010c). This accounts for 8-10% of their vegetable dishes (Christensen, 1997). In the tropics, around 200 species of ferns are eaten regularly. Many edible species have been recorded from the Old World tropics and they make a significant dietary contribution. The fern most commonly eaten, either as salad or as vegetable after cooking, are *Diplazium esculentum* (paku tanjung), *Acrostichum aureum* (paku larat), *Stenochlaena palustris* (lemiding) and *Helminthostachys zeylanica* (tunjuk langit) (Powell in Paijmans, 1976; Henderson and Hancock, 1988; Jacquat, 1990).

The way in which these vegetable ferns are prepared varies in accordance with the cook's preference for salad to steamed, boiled, or fried dishes. In an experiment carried out in the Philippines, Kalimantan and East Malaysia, cooked fiddleheads of the following ferns were tried as a vegetable or as a component of a stew: *Acrostichum aureum, Angiopteris evecta, Blechnum orientale, Cyathea contaminans, Diplazium esculentum, Nephrolepis hirsutula, Pleocnemia irregularis, Pteris ensiformis,* and *Stenochlaena palustris*. *Diplazium esculentum* was found to be the most palatable.

Other factors determining the suitability of fern fronds as vegetables include the production rate of new leaves and the availability of young fronds throughout the year. There have been some experiments to bring *Diplazium esculentum* into cultivation, but up till now most if not all of the supply in the markets is still harvested from the wild (de Winter and Amoroso, 2003).

Other ferns species used as vegetables include the *Asplenium ensiforme, Ceratopteris thalictroides, Nephrolepis biserrata, Phymatosorus longissimus* and *Microsorum alternifolium*.

The starchy paste of the sporocarps of the species *Marsilea drummondii* is made into cakes called “nardoo” which is eaten by the natives of Australia (Mannar Mannan *et al.,* 2008). The fiddleheads of *Pteridium aquilinum* (bracken) are also cooked as vegetable in Japan and are believed to be responsible for the high rate of stomach cancer in Japan. It is also one of the world’s most important agricultural weeds, especially in the British highlands, and often poisons cattle and horses. The fiddleheads of the *Matteuccia struthiopteris* (ostrich fern) and *Osmunda cinnamomea* (cinnamom fern) are also cooked as vegetable in North America (Moran 2004; Lord, 2006).

Ornamental

Ferns do not have much economic value, but they have great aesthetic value due to their grace and delicate beauty and hence are cultivated as ornamental plants. Before introducing a species as an ornamental some key factors should be considered that may influence its commercial value. These factors comprise a combination of characteristics that make a fern attractive to customers and are also properties that are important to the commercial growers. Generally, ornamental ferns have the following common characteristics: closely placed fronds which give them a full foliage look, symmetry in overall outline, small to medium size, an evergreen habit and at least one unique characteristic that makes them special, for examples colour, texture, or shape. Moreover, they should be able to stand adverse cultural conditions and not be too sensitive to relative humidity or temperature when marketed for indoor use, or need to be inexpensive enough to be disposable. Commercial nurseries demand species that are inexpensive to produce and deliver to the market. Fast-growing species are preferred, such as those that can be reproduced by spores or mass vegetative tissue culture.

The ferns should be resistant to diseases and pests. They should also not easily be damaged during transport from the grower to the market (de Winter and Amoroso, 2003).

Ferns have been successful in acclimatizing and propagating in favourable conditions. They can grow well in moist and shady places in the gardens where other plants generally cannot grow. The ferns can be grown very well in the ground or in pots, as epiphytes on tree trunks or in hanging baskets. Ferns are cultivated as ornamentals either indoors in houses or outdoors in the botanical gardens due to their delicate beauty and grace. Several species of the *Lycopodium* are used in decoration. These are used mostly in Christmas Wreaths and are popularly known as “Christmas green”. *Lycopodium volubile*, a beautiful forest species, keeps well after being collected and is generally used for table decoration. Some *Selaginella* species have got feathery moss-like foliage and are greatly admired when grown in pots for table decoration. Many species have various shades of green. Some ferns have metallic and many hued tints particularly uncommon bluish and bronze colours. For example, the leaves of *Selaginella serpens* are bright green in colour in the morning and during the day they gradually become paler and at night they again resume their green colour. The *Drynaria* species can also be grown as ornamentals in the gardens, in the ground or as epiphytes. They can also be grown in baskets for indoor decoration which can be kept on stands or as hanging baskets. *Pteris,* popularly known as “The Brake”, is commonly cultivated as an indoor potted plant and in botanical gardens. *Adiantum* species are also cultivated for decoration purposes. The “Golden fern” *Pityrogramma chrysophylla, Cheilanthes tenuifolia, Platycerium bifurcatum, Asplenium nidus* and “Rabbits’ Ear Fern” *Hemionitis arifolia* are all cultivated for their splendid beauty and grace. *Ceratopteris* and *Marsilea* ferns can also be used as ornamentals by growing them in pots and keeping them in a pond (**Figure 21**). Some *Diplazium* species have a gregarious trunk and become tree like in nature and are of great aesthetic value (Burkill, 1966; Quisumbing, 1978; Rost, et al., 2006). Some *Dryopteris* and *Asplenium* species are cultivated in some botanical gardens due to their grace (Johnson, 1977).

The "florist's fern" is *Rumohra adiantiformis,* a pantropical fern with very thick leathery leaves which keep for days, in or out of water. It is grown mostly in Florida and Costa Rica, and the international trade is worth millions of pounds. Tree ferns (*Cyathea*) are cut by the million each year and their trunks used for growing other plants, particularly orchids (Christensen, 1997).

Other species could also be developed, although it is questionable whether growers are able to compete on the international markets due to transport costs and plant-hygiene import restrictions. For local markets, ferns are often gathered from the forest. Most of these are common and thus the collection activities can have adverse impacts on the forest diversity.

Medicine

The pteridophytes constitute the primitive vascular plant group which is found scattered all over the world. Although, not much consideration has been given towards the utility of ferns yet they possess economic importance including medicinal ones. No pteridophytes are used at present as a source of pharmaceutical compounds, although some of the constituents are being synthesized. In the past it has been speculated as to whether the supposed medicinal value of ferns is due to their properties or if it should be attributed to the psychological and placebo-effect. It is noteworthy, however, that the same or related fern species have

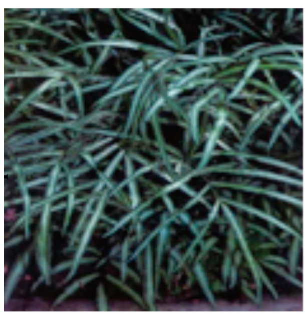
A.H. Moin

Asplenium nidus

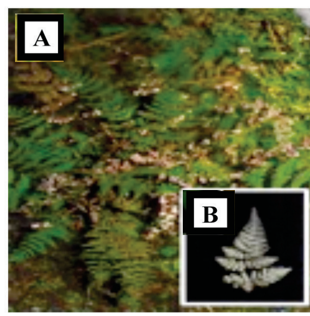
M.S. Fareeq

Pteris ensiformis

M.S. Fareeq



Pteris cretica

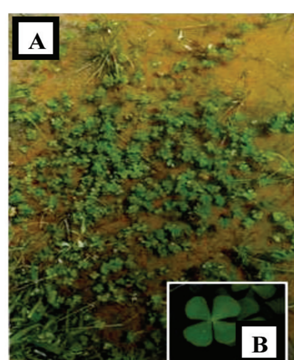


A. Kahar

Cheilanthes farinosa
(A. Sporophyte; B. Frond)

A. Kahar

Drynaria quercifolia



M.S. Fareeq

Marsilea crenata
(A. Sporophyte; B. Frond)

Figure 21 Ornamental ferns

found similar medicinal applications even on different continents. Furthermore, in several cases laboratory research has revealed biological activities of fern extracts that could account for its use in traditional and herbal medicine (de Winter and Amoroso, 2003; Parihar and Parihar, 2006).

The most common uses of ferns are to treat skin problems and wounds, fever, cough, tonic, reproductive problems and also as insect repellent (Nair, 1959; Dixit, 1974; Perry and Metzger, 1980). Some ferns are used to treat common diseases such as cuts, ulcer, dysentry and as protective medicine after childbirth (Perry and Metzger, 1980; Kamaruddin Mat Salleh and Latif, 2002; Jaman and Umi Kalsom, 2010b). Others were reported to be antiviral, antipyretic, anti-inflammatory, antibacterial and also used in the treatment of jaundice (Farnsworth et al., 1985; Benjamin and Manickam, 2007). Medicinal uses of more than 20 species of local ferns by various ethnic groups have been documented (Burkill, 1966; Bidin, 1985). The medicinal values of ferns are summarized in Table 1.

Table 1 The medicinal values of Malaysian Ferns

Botanical name (local name)	**Uses part**	**Medicinal use**
Acrostichum aureum (paku larat)	Rhizome	Antihelmintic, vulnery and for healing invetebrate ulcers
	Fertile fronds	Antifungal agent, syphilitic ulcers
Angiopteris evecta (paku gajah)	Leaves	Dysentery
	Spores	Leprosy and skin disease
Angiopteris angustifolia (paku gajah besar)	Leaves	Stomach ache
Asplenium nidus (sakat, semun, paku rajang)	Whole plant	Depurative and sedative
	Leaves	Lotion to treat fever, ease labour pain
Blechnum orientale (paku merah)	Fronds	Urinary bladder complaints, intestinal wounds, anthelmintic
Ceratopteris thalictroides (paku roman, paku ruan)	Fronds	Poultice for skin disease
Cheilanthes tenuifolia (paku telur belangkas, resam padi)	Rhizome and root	Hair tonic

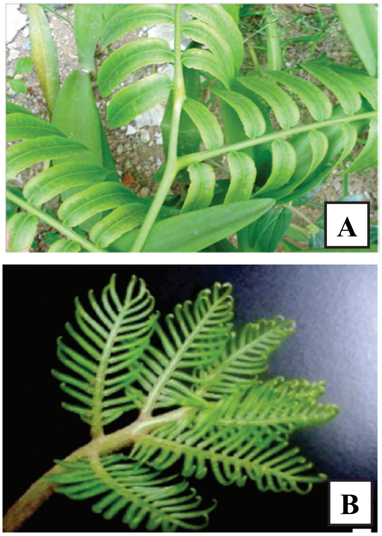
Cibotium barometz (penawar jambi, bulu pusi)	Root	Treatment of lumbago and itching
Dicranopteris linearis (resam)	Leaves	Poultice to control fever, treatment of boils, ulcers and wounds
Diplazium asperum (paku kijang)	Leaves	Treatment of swellings and also for relieving pain
Diplazium esculentum (paku tanjung, paku benar, paku sungai)	Leaves	Tonic after childbirth
Drynaria quercifolia (kepala tupai)	Rhizome	Cough and fever
Drynaria sparsisora (sakat laipang)	Rhizome	Rhizome boiled and mixed with the bark of *Inocarpus edulis* to treat gonorrhea
Helminthostachys zeylanica (tunjuk langit, akar paku)	Leaves Rhizome	Tonic to treat syphilis Treatment of whooping cough
Lygodium circinnatum (ribu-ribu duduk, ribu-ribu bukit)	Rhizome	Poultice for healing wounds
Lygodium flexusoum (ribu-ribu gajah)	Rhizome	Gonorrhea, scabies, rheumatism, eczema

Lygodium microphyllum (ribu-ribu, selada)	Leaves	Dysentry. Poultice for skin disease and swelling. Crushed leaves used to cure cough
Lygodium japonium	Leaves	Used as an expectorant
Microsorium rubidium (paku wangi, sakat hitam)	Rhizome	Poultice to treat wounds
Nephrolepis auriculata (paku uban)	Fronds	Reduce high blood pressure
Ophioglossum pendulum (simbar gadang, kumpai lubang)	Fronds	Hair tonic
Osmunda regalis	Whole plant	Treatment of rickets, rheumatism, intestinal gripping and used as a tonic and styptic
Pityrogramma calomelanos	Whole Plant	Remedy for kidney troubles
	Rhizome	Treatment of dysentery
Platycerium hottumii (pakis tanduk rusa)	Leaves	anti-swelling properties
Pleocnemia irregularis	Rhizome	Treatment of skin disease
	Leaves	Treatment of diarrhoea

Pyrrosia lanceolata (bulu ayam, tetumpang)	Whole plant	Cold and sore throat
Pyrrosia nummularifolia (berunas jantan, paku wangi, sakat hitam)	Leaves	Treatment of cough and anticancer properties
Pyrrosia piloselloides (duit-duit, sakat ribu-ribu)	Leaves	Treatment of skin diseases
Schizaea dichotoma (payung ali, misai rimau)	Rhizome	Relieves cough and throat infection
Stenochlaena palustris (lemiding)	Leaves	Cure fever
Tectaria blechnoides (meroyan dawai, meroyan paku)	Leaves	Treatment after childbirth
Tectaria crenata (paku kikir)	Whole plants	Whole plant boiled with *Pleonele angustifolia* for the treatment of gonorrhea

A.H. Moin

Platycerium coronarium

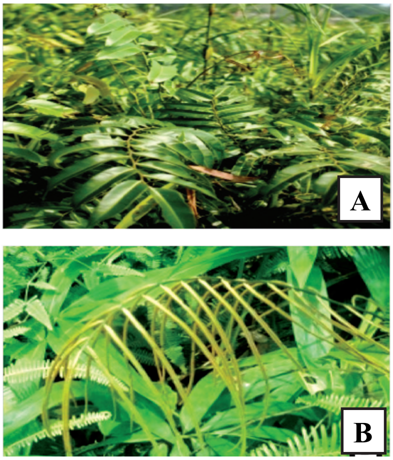


Rusea Go

Angiopteris evecta
(A. Sporophyte; B. Young shoot)

Rusea Go

Pityrogramma calomelanos



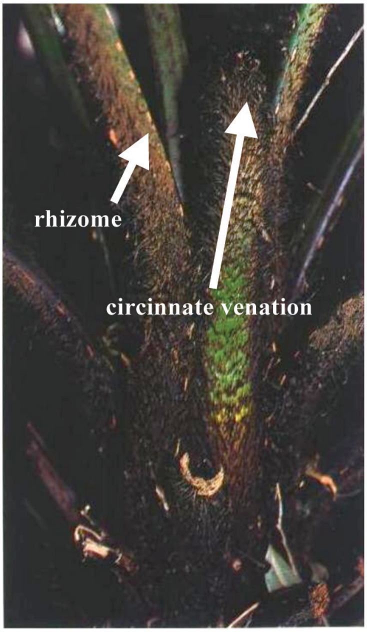
Stenochlaena palustris
(A. Sporophyte; B. Fertile Frond)

Figure 22 Medicinal ferns

These ferns have great medicinal value. Additionally, quite a number are used as food, shelter and ornamentals. They are highly prized as foliage ornamentals due to their beauty and grace, whether indoors or outdoors. Thus, researchers have stressed on the need of conservation of various ferns. In Peninsular Malaysia, quite a number of taxa of ferns and fern allies from various regions, which had been recorded earlier, have been eradicated or lost in recent years. Moreover, population densities have also decreased considerably. This is primarily due to deforestration, with the result that quite a number of species have been lost and many have become endangered (Parris and Kiew, 2010). Hence, while the exploitation of the ferns for their economic utility, including ornamental use, must be done, but at the same time, care should be taken for their conservation. In view of this, it is suggested that rare species of ferns and fern allies should be protected from merciless collection and destruction in the hills and their cultivation and propagation be given special attention so that we are not deprived of the economic value of this unique group of plants. If these guidelines can be followed strictly and if we can maintain our biodiversity, further studies on ferns could bring many more medicinally important species to light.

Structural Materials

Wood from tree ferns (*Cyathea* and *Cibotium*) are sometimes used as instant construction material for bridges and fences. The fibrous material is resistant to decay, particularly by termite, and long-lasting. In the tropics, the trunks are used for the construction of houses too, but possibly only where these tree ferns are plentiful and other suitable timber is scarce. The stem can also be cut into sections of desired dimensions, polished and then made into vases, pencil holders and umbrella holders, or split and the harder portion used for inlaying or making fancy boxes and frames (Quisumbing, 1978; Henderson and Hancock, 1988).



Cibotium barometz

Cyanthea contaminans

Figure 23 Structure materials (Photographed by R. Jaman)

Fibrous splints can be obtained from the petioles and rachises of various species, and these are used for making ropes and wickerwork. *Lygodium* is extensively used in Thailand to make a wide range of small boxes, belts and baskets, body jewellery and other items for the handicraft and tourist industry (Jacquat, 1990).

Other Uses

Ferns have traditionally been used for various other purposes. The decorative value of ferns and their allies have invited their use for personal decoration, either casual or for ceremonial occasions. Especially fibrous species (*Dicranopteris* and *Lygodium*) or those that form long, flexible stings that can be interwoven without breaking (*Selaginella, Lycopodium*) are suitable for this purpose. Houses and ceremonial places are also decorated with ferns, either by adorning them on purpose, or by just allowing ferns to remain where they appear spontaneously. Ferns have also found a place in rituals and magic. The leaves of *Nephrolepis* were placed among the bones of deceased close relatives at death ceremonies in New Guinea while magical properties were attributed to *Blechnum orientale, Hemionitis arifolia* and *Drynaria.* Further, the sandpaper-like qualities of *Equisetum* have led to its use in shaping and smoothening tools, ornaments and weapons, but is also acknowledged to be useful for cleaning pans and other cooking utensils (Powell in Paijmans, 1976). Additionally, the young fronds of *Phymatosorus scolopendria* are spread on the bed to keep off bed bugs (Mannar Mannan et al., 2008). Ferns of the genus *Azolla,* which are very small, floating plants that do not resemble ferns, are known as the mosquito fern, and are used as a biological fertilizer in the paddy fields of South East Asia, taking advantage of their ability to fix nitrogen from the air into compounds that can then be used by other plants. These plants are carefully propagated from year to year because of their importance as the source of nitrogen for the growth of the rice plants. Over two billion people are almost entirely dependent on this fern for their livelihood. In the field it can often be recognized by the brilliant red colour of the small plant floating in clear areas in swamps. It is estimated that each year the *Azolla* converts more atmospheric nitrogen into a form available for plant growth than all the legumes. (Lumpkin and Plucknett, 1980).

Several ferns are invasive species, including the Japanese climbing fern (*Lygodium japonicum*), mosquito fern and sensitive fern (*Onoclea sensibilis*). The Giant water fern (*Salvinia molesta*) is one of the world's worst aquatic weeds.

Ferns have also been found to be useful in the removal of heavy metals, especially arsenic, from the soil. *Pteris vittata* (brake fern), is used to absorb arsenic from the soil and *Microsorum pteropus* (Java fern), is one of the most popular freshwater aquarium plants (May, 1978; Lord, 2006).

Although many of the traditional uses of ferns have been abandoned and replaced by modern materials, nevertheless new applications still arise. Ferns frequently are the subject of various fields of scientific research. Modern uses include widely differing applications such as for sewage water treatment, hydrogen production, gold prospecting, compositing and the development of new pharmaceutical products.

Chemical Constituent in Ferns

Over the past thirty-five years there has been increased interest in the chemical constituents of ferns, with compounds being reported in 184 of the 402 genera listed by Crabbe *et al*. (1975). This activity has been stimulated by (a) the recognition that constituent distribution can be a valuable tool in fern systematic, (b) increased pharmaceutical and toxicological interest, (c) improvements in separation and identification techniques and (d) the reliazation that there is a general lack of data on the chemistry of ferns. A number of more comprehensive chemical surveys of ferns have been carried out (Cooper-Driver and Hanfler, 1983; Umi Kalsom, 1993; Umi Kalsom, 1994a). The groups of compounds used in fern classification are sesquiterpenes and triterpenoids (Das and Mahato, 1983), natural carcinogens, polysaccharides (Bailey and Pain, 1970), non-protein amino acids (Peterson and Fairbrothers,

1971) and flavonoids (Wollenweber and Dietz, 1980; Umi Kalsom *et al.,* 2003).

Ferns have probably been more widely surveyed for flavonoids than for any other groups of secondary plant constituents. There are a number of reasons for this. Flavonoids are widely distributed and are diverse in structure. They are stable, which allows the analysis of not only fresh materials but also herbarium samples. Flavonoids are relatively easy to detect on chromatography paper when viewed in ultraviolet light and often undergo significant colour changes when fumed with ammonia vapour. Flavonoids require relatively cheap apparatus for separation and identification. The increased interest in flavonoid components in ferns has paralleled the general growth in flavonoid phytochemistry (Harborne and Mabry, 1982; Umi Kalsom 1994a). Studies have generally been limited to sporophytes except for those on *Blechnum brasiliense* (Laar, 1966), *Dryopteris intermedia, D. marginalis* (Peterkin and Fairbrothers, 1980) and *Lygodium japonicum* (Laar and Vaudois, 1976).

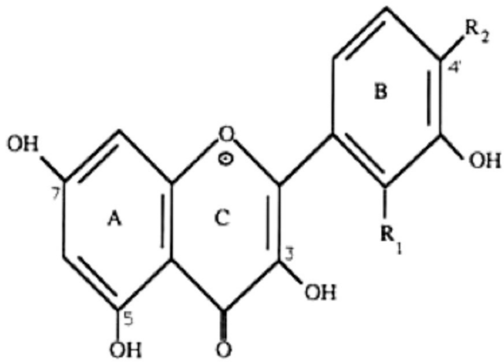
(a) Flavonoid Distribution in Ferns

Flavonoids are widely distributed in ferns. Proanthocyanins, glycosides of the flavones, apigenin and luteolin and of kaempferol, and quercetin found in angiosperms are present in the ferns. Flavonoid derivatives such as luteolin, apigenin, quercetin and kaempferol have been detected in acid hydrolysed extracts of around twenty fern genera (Harborne, 1967). Hegnauer (1962) and Bate-Smith (1954) have recorded procyanidin and prodelphinidin in fifteen of twenty species surveyed. Kaempferol 3,4'-*O*-diglucoside is a rare natural product; which was isolated for the first time (Ishikura and Hayashida, 1979) from the seed-coat of *Ophiopogon jaburan* and has subsequently been found in two *Prunus* species; *P. avium* and *P. cerasus* (Henning and Hermann, 1980). Later, this flavonoid was reported for the first time in the fern *Cystopteris fragilis* (Imperato, 1983a). Akabori and Hasegawa (1970) have isolated the flavanone derivative, namely pinocembrin, in glycosidic form from *Dennstaedtia wilfordii.* Later, naringenin 7-*O*-L-arabinopyranosyl-(1-6) glucoside was obtained from the fronds of *Ceterach officinarum* (Imperato, 1983b). However, myricetin, which is present in 10% of all flowering plants examined (Voirin, 1970), has been found so far in only one fern, *Leptochilus zeylanicus.*

Ferns do contain other flavonoids which are regarded as primitive. These include glycosides of the 3-deoxyanthocyanidins, apigenidin and luteolinidin, which have been found in mosses, and also contain a number of *C*-methylated flavanones, chalcones and flavones such as eriodictyol 7-*O*-methyl ether, triangularin and pityrogrammin (Wollenweber, 1981).

The presence of flavonoid aglycones in the Asplenioid ferns genus *Asplenium* was previously reported by Voirin (1967). He found kaempferol 4'O-methyl ether in *A. diplaziosorum.* Later, Voirin (1970) reported the distribution of flavonoid aglycones in 19 species of *Asplenium.* He studied mainly European species and a few species from Central Africa. He found kaempferol in 18 species and quercetin in six species. Umi Kalsom and Harborne (1991a) studied the flavonoid profile in twelve species of *Asplenium* from Malaysia and three species from England. As expected, twelve of the fifteen species examined contain kaempferol and all but four of these also possess quercetin. Only in the samples of *A. scolopendrium* and *A. marinum* could these flavonols not be detected, but kaempferol 3-*O*-methyl ether was found in *A. marinum.* Previous surveys of the Aspleniaceae (Voirin, 1970;

Harborne et al., 1973; Imperato, 1985) for flavonoid aglycones have indicated that kaempferol is more common than quercetin, in this group. The present finding in 80% of Malaysian *Asplenium* studied confirms this pattern. Proanthocyanidins based on delphinidin and cyanidin were present in *A. amboinense* and *A. adiantum-nigrum*. Voirin (1970) studied nineteen species of *Asplenium,* mainly European species and a few species from Central Africa. He found that proanthocyanidins based on delphinidin and cyanidin were widely distributed, being present in twelve of the nineteen species investigated (**Figure 24A**). On the other hand, flavonoid derivativesextracted from twelve *Asplenium* species collected from local habitats in Malaysia, proanthocyanidins were present in only one viz: *A. amboinense* (Umi Kalsom and Harborne, 1991a). These differences may be attributable to the geographical differences in the chemistry of European and Malaysian *Asplenium*. In the fern *Lunathyrium japonicum,* there also seemed to exist a correlation between geographical and flavonoid composition. The flavonoid pattern in samples from Malaysia appears to be different from that from Japan. Hiraoka (1978) found that *L. japonicum* from Japan produced vitexin, orientin, quercetin-3-*O*-glucoside and kaempferol-3-*O*-glucoside in the frond extracts. The specimen from Malaysia produced the same flavones *C*-glycoside, but it also produced quercetin-3-*O*-rutinoside, vicenin-2 and unidentified kaempferol *O*-glycosides (Umi Kalsom and Harborne, 1991b). Umi Kalsom and coworkers (2003) also encountered this phenomenon when they analysed the flavonoids in the fronds of the species of *Gleichenia.* In the samples from Malaysia, they found orientin and vitexin. Previously, Wallace and coworkers (1983) studied the same species of *Gleichenia* from Hawaii and found different flavonoid patterns. They found quercetin-3-*O*-rutinoside, quercetin-3-*O*-glucoside and kaempferol-3-glucoside but they also found kaempferol-3-*O*-rutinoside as well. Furthermore, quercetin-3-*O*-rutinoside was identified as a major component in all species except the *G. intermedia.* Quercetin-3-*O*-glucoside and kaempferol-3-*O*-glucoside was observed as minor constituents of the two species studied. These findings, however, are still to be confirmed by analysis of further samples from the different regions.

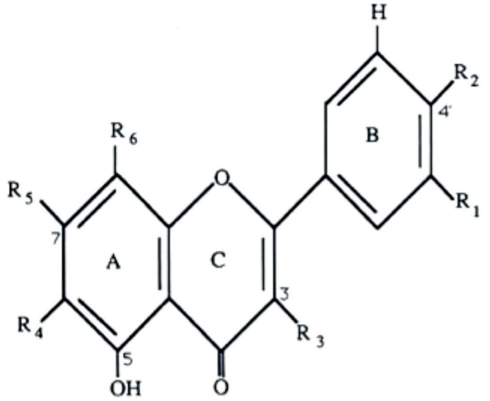


Cyanidin, R_1=OH; R_2=H
Delphinidin, R_1= R_2=OH

Figure 24A Structure of proanthocyanidins

Both methylated flavones, genkwanin and acacetin, were reported for the first time in the fern *Notholaena bryopoda* (Polypodiaceae) (Wollenweber, 1982). Later, these methylated flavones were detected only in *A. normale.* Hispidulin and pectolarigenin were detected in *A. glaucophyllum* in trace amounts due to its relatively low concentration and the small amount of sample available (Umi Kalsom and Harborne, 1991c). Scutellarein was previously found in leaves of the flowering plant *Scutellaria galericulata* and in roots of *S. rivularis* (Barberan, 1986). Later, scutellarein and scutellarein 6-*O*-glucoside were detected in *A.*

belangeri. Hispidulin, pectolinarigenin and scutellarein have not been reported previously in ferns, and their occurrence suggests that the flavonoid metabolism of the fern genus *Asplenium* is quite advanced (**Figure 24B**).



Acacetin, $R_1= R_3= R_4= R_6$; R_2=OMe; R_5=OH
Kaempferol, $R_1= R_4= R_6$=H; R_2= R3=OH; R_5=OH
Genkwanin, $R_1= R_3= R_4= R_6$=H; R_2=OH; R_5=OMe
Hispidulin, $R_1= R_3= R_6$=H; R_2=OH; R_4=OMe; R_5=OH
Scutellarein, $R_1= R_3= R_6$=H; $R_2= R_4= R_5$=OH
Pectolinarigenin, $R_1= R_3= R_6$=H; $R_2= R_4$=OMe; R_5=OH

Figure 24B Structure of flavones and flavonols

Accumulation of these 6-hydroxylated and 6-methoxylated flavones is a characteristic feature of the more advanced angiosperm families such as Labiatae and Scrophulariaceae (Umi Kalsom et al., 1994).

Flavone *C*-glycosides, namely vitexin and orientin, were only detected in one of the species studied, *A. amboinense* (Umi Kalsom et al., 1994). The occurrence of vitexin in ferns has been previously reported in *Cyathea faurier* and *Sphenomeris chusana*, by Ueno and coworkers (1962). Orientin is a common constituent in five *Cyathea* species (Hiraoka and Hasegawa, 1975). Both vitexin and orientin were also reported to occur in seven *Deparia* (*Lunathyrium*) species (Hiraoka, 1978). Thus, the presence of these flavones *C*-glycosides in the species studied increases the number of fern taxa with these types of flavones.

Several flavones *C*-glycosides were isolated from the pinnae of *A. belangeri, A. tenerum* and *A. amboinense* (Umi Kalsom and Harborne, 1991d). Schaftoside, isoschaftoside, vicenin-1 and isoviolathin were isolated from *A. belangeri.* Schaftoside and isoschaftoside, as well as lucenin-2, were also detected in *A. tenerum.* Lucenin-2 has been unambiguously characterized in the moss *Hedwigia ciliata* (Osterdahl, 1978) and in the weed *Spergularia rubra* (Bouillant et al., 1979). Here this flavonoid is described for the first time from the Aspleniod ferns. Vicenin-2 has been found in many plants (Chopin et al., 1979) and also been detected in two species of bryophytes, *Hedwigia ciliata* (Osterdahl, 1979) and *Plagiochila asplenioides* (Mues and Zinsmeister, 1976). In addition, it was detected in the ferns of *Angiopteris* (Marattiaceae), along with schaftoside, isoschaftoside, vicenin-1 and isoviolanthin (Wallace et al., 1981). Later it was also detected in the pinnae of *A. belangeri.*

Harborne and coworkers (1973) who studied the flavonol glycosides and methylated flavonols of ferns and hybrids of the Appalachian species of *Asplenium* found a series of kaempferol derivatives in the fronds of three parental species of the Applachian *Asplenium* complex. *A. platyneuron* is characterized by the presence of the 7-*O*-glucoside of kaempferol 3,4’-*O*-dimethyl ether and kaempferol 3,7-*O*-diglucoside, with an aliphatic acyl attachment. By contrast, *A. rhizophyllum* contains caffeoyl complex of kaempferol glycosides. *A. montanum,* in addition to having the glycosyl xanthones (Smith and Harborne, 1971), has another two kaempferol glycosides (Harborne et al., 1973). Further flavonoid studies of the Italian *Asplenium* were carried out by Imperato (1985). He found several flavonol glycosides based on kaempferol and quercetin in six species. Thus, kaempferol 3,7-*O*-dirhamnoside, kaempferol 3-*O*-rhamnoside-7- *O*-arabinoside and kaempferol-3- *O*-arabinoside-7-*O*-rhamnoside were found in the fronds of *A. trichomanes* (Imperato, 1979a). Kaempferol 3-*O*-glucoside and a new natural product, kaempferol 3-*O*-β-D-(6"-sulphate)glucoside, have been isolated from the fronds of *A. filix-femina* (Imperato, 1979b). Kaempferol 3-*O*-gentiobioside had earlier been identified in the plant, *Primula sinensis* (primulaceae) (Harborne and Sherratt, 1961). It was also isolated, together with kaempferol 3-*O*-(gentiobioside-6'-sulphate), from *A. fontanum* (Imperato, 1980). Imperato (1983c) also reported the occurrence of three flavonoids in the frond extracts of *A. septentrionale,* which were identified as quercetin 3-*O*-glucoside, and two new products, kaempferol 3-*O*-sophoroside-7-*O*-glucoside and quercetin 3-*O*-(3"-sulphate)glucoside. Five flavonoid glycosides were isolated from *A. bulbiferum,* of which four were reported for the first time in fern tissues. These are kaempferide 3,7-*O*-diglucoside, kaempferol 3-*O*-rhamnoside-7-*O*-glucoside, kaempferide 3-*O*-glucoside -7-*O*-rhamnoside and kaempferol 3-*O*-glucoside-7-*O*-galactoside (Imperato, 1984a, 1984b, 1985). The fifth is kaempferol 3,7-*O*-diglucoside (Imperato, 1983), which had previously been found in *A. rhizophyllum* (Harborne, et al., 1973) and *A. trichomanes* (Imperato, 1979a, 1979b). Subsequently, several flavonol glycosides, kaempferol 3-*O*-gentiobioside-7, 4'-*O*-diglucoside, were extracted from *A. nidus*, kaempferol 3-*O*-glucosylglucoside-4-*O*-glucoside was isolated from *A. septentrionale* (Imperato, 1990), two methylated kaempferol

7-*O*-glycosides (**Figure 24C**) were isolated from the European fern, *A. marinum* (Umi Kalsom and Harborne, 1991e), myricetin 4'-methyl ether 3,7dirhamnoside was isolated from *A. antiquum* (Mizuno et al., 1991) and kaempferol 3-*O*-gentiobioside-4'-*O*-glucoside was isolated from *A. incisum* (Iwashina et al., 2000). The present discovery of 3-*O*-methyl ether and 3,4'-*O*-dimethyl ether of kaempferol is not unexpected since Voirin (1967) has already reported the presence of kaempferol 4'-*O*-methyl ether in *A. diplaziosorum.* This flavonol monomethyl ether has also been found as the free phenol in the farinose exudates on fronds of three genera: *Pityrogramma, Cheilanthes* and *Notholaena* (Wollenweber, 1982). Earlier, the 7,4'-*O*-dimethyl ethers and 3,7,4'-*O*-trimethyl ethers of kaempferol had been found in the farinose exudates of the fern *Cheilanthes* by Erdtman and coworkers (1966). In addition, the 3,4'-*O*-dimethyl ethers of kaempferol had been found once before in *A. platyneuron* (Harborne, et al., 1973). It was also detected in the farinose exudates of the fern *Notholaena,* along with the 3-*O*-methyl, 7-*O*-methyl, 3,7-*O*-dimethyl and 3,7,4'-*O*-trimethyl ethers of kaempferol (Wollenweber, 1984).

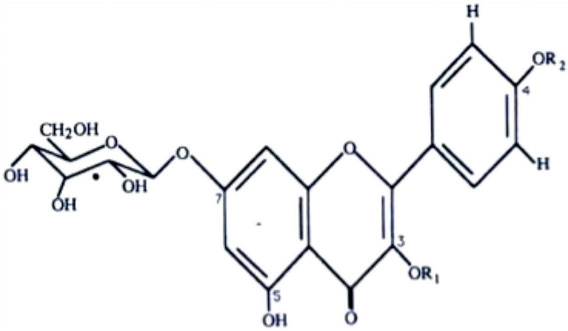


Figure 24C Structural formula of kaempferol derivatives

Kaempferol 3-*O*-methyl ether 7-*O*-glucoside, R_1=Me, R_2=H
Kaempferol 3,4'di-*O*-methyl ether 7-*O*-glucoside, R_1 = R_2=Me

Thus, the presence of kaempferol 3-*O*-methyl ether-7-*O*-glucoside in *A. marinum* and myricetin 4'methyl ether 3,7-*O*-dirahmanoside in *A. insicisum* adds to the considerable number of glycosidic forms of flavonol methyl ethers that have been isolated from fern leaves. In addition, these glycosides are important because flavonols with one or more methyl ethers in free form are inhibitors of some enzyme activities and are toxic to living cells (Umi Kalsom and Harborne, 1991e).

(b) The role of flavonoids in fern systematics

The distribution of flavonoids in ferns can be used to deduce taxonomic relationships at various levels of fern classification. Cooper-Driver (1977) studied the flavonoid patterns of the aerial of Psilotales and Filicales. She stated that her results concerning the flavonoid patterns of the Psilotales and Filicales provided evidence to contradict Bierhosrt's (1977) speculation on the phylogeny of these taxa and support the idea of separating Psilotales from Filicales as suggested by Pichi-Sermolli (1973). Psilotales synthesize only amentoflvone and related biflavonyls which are totally absent in Filicales. The primitive filicales contain flavonols and proanthocyanindins which are also found in all other filicalean families.

Chemotaxonomic studies of the ferns *Cyathea* (Hiraoka and Hasegawa, 1975), Marattiaceae (Wallace et al., 1979a; Wallace et al, 1979b), Aspleniaceae and Athyriaceae (Umi Kalsom et al., 1994), *Asplenium* (Iwashina et al., 2000) and *Sphaerostephanos* (Umi Kalsom, 2006) also illustrate the taxonomic significance of flavonoids. Species of *Cyathea* (Hiraoka and Hasegawa, 1975),*Pityrogramma, Cheilanthes* and *Notholaena* (Wollenweber, 1978) can be delimited on the basis of their flavonol glycosylation patterns. Within Marattiaceae, *Angiopteris* is characterized by the presence of *O*-glycosyl and *C*-glycosyl derivatives of apigenin, including violanthin and isoviolanthin, whereas *Marattia* contains flavonol *O*-glycosides instead (Wallace et al, 1979a). Both *C*-glycosyl apigenin derivatives and flavonols are found in *Danaea*, but so far, *Christensenia* has been shown to contain only an unknown kaempferol *O*-glycoside (Wallace et al., 1979b).

Within Athyriaceae, *Athyrium, Diplazium* and *Deparia* can be distinguished on the basis of their overall flavonoid profiles. Procyanidin and flavonol glycosides were found in the *Athyrium* representatives studied, whereas in addition flavone di-*C*-glycosides were found in *Diplazium.* Species of *Deparia* were very similar in their flavonoid patterns to those of *Diplazium,* except that the latter lack proanthocyanidins and the flavone di-*C*-glycosides of *Deparia* were replaced in *Diplazium* by flavones mono-*C*-glycosides. Furthermore, flavonoid chemistry in the fern family Athyriaceae (consists of *Athyrium, Diplazium* and *Deparia*) is quite different from that of the Aspleniaceae (*Asplenium*), and this supports their taxonomic separation. Athyriaceae is considered as a more primitive family as they consist of flavonol *O*-glycosides, whereas Aspleniaceae, the more advanced family, accumulates flavones, both *C*-and *O*-glycosides (Umi Kalsom et al., 1994).

Iwashina and coworkers (2000) studied the flavonoid compositions in *Asplenium normale, A. foreziense, A. fontanum* subsp. *fontanum* and subsp. *pseudofontanum, A. obovatum* subsp. *obovatum* and var. *protbillotii, A. obovatum* subsp. *lanceolatum* and *A. incisum.* They found that *A. fontanum* subsp. *fontanum* and subsp. *pseudofontanum, A. foreziense* and *A. obovatum* are closely relatedm not only morphologically but also chemically. On the other hand, they also suggested that chemical races occur in *A. fontanum.* This is due to the occurrence of a sulphated flavonol in an Italian *A. fontanum* and its absence in a Spanish sample. Japanese

A. incisum also contained kaempferol 3-*O*-gentiobioside, but it was accompanied by kaempferol 3-*O*-gentiobioside-4'-*O*-glucoside, kaempferol 3-*O*-glucoside and quercetin 3-*O*-diglucosiode which could not be detected from other *Asplenium* taxa examined in this survey. *A. incisum* is morphologically related to *A. normale* which is widely distributed in Asia, Africa and Hawaii. However, the flavonoid characters of *A. incisum* (flavonols) were clearly different from those of *A. normale* (flavones), which had previously been reported by Umi Kalsom and Harborne (1991c) and Iwashina and Matsumoto (1994).

On the basis of the presence of flavonoid glycosides and aglycones in species of *Sphaerostephanos,* it was concluded that the *Sphaerostephanos* species should be divisible into two groups (Table 2). Species of Group A contain both flavonoid glycosides and aglycones, whereas species of Group B, have a complete lack of flavonoids.

The species of Group A do vary in their glycosides such that it is possible to distinguish some of them by their flavonoid patterns.

S. heterocarpus accumulates kaempferol 3-*O*-glucoside and isorhamnetin 3-*O*-glucoside which are not found in the other four species. Two species of *Sphaerostephanos, S. polycarpus* and *S. unitus,* contain kaempferol, quercetin, quercetin 3-*O*-galactoside and kaempferol 3-rhamnoside. However, they can be chemically distinguished from one another because *S. polycarpus* accumulates schaftoside and isoschaftoside whereas *S. unitus* accumulates quercetin 3-galactoside and kaempferol 3-galactoside. The last two species, *S. penniger* and *S. larutensis,* have quercetin and quercetin 3-galactoside, but *S. penniger* produces isorhamnetin as well (Umi Kalsom, 2006).

Flavonoid data have been found to show correlations with existing disciplines such as palynology and morphology, and

Table 2 The distribution of flavonoid glycosides in the pinnae of *Sphaerostephanos* sp.

Taxon, collector and locality	Flavone *C*-glycosides			Flavanols and flavones				Flavanol *O*-glycosides					
	SCH	ISCH	Ap-7-glu	Km	Qu	Ap	Fisetin	Qu-3-glu	Qu-3-gal	Isorham-3-glu	Km-3-glu	Km-3-rha	Km-3-gal
Sphaerostephanos													
Group A:													
S. heterocarpus (Bl.) Holtt. (Nancy Jacob 11, Genting Sempah, Pahang, W. Malaysia, 23.7.1991)	-	-	+	+	+	+	-	-	-	+	+	+	-
S. hendersonii Holtt. (Nancy Jacob 15, Genting Sempah, Pahang, W. Malaysia, 23.7.1991)	-	-	+	-	-	+	-	-	-	-	-	-	-
S. polycarpus (Bl.) Copel. (Umi Kalsom 276, Kuala Perlis, Perlis, W. Malaysia, 25.8.1991)	+	+	-	+	+	-	-	-	+	-	-	+	-
S. unitus (L.) Holtt. (Nancy Jacob 2, Gunung Ulu Kali, Pahang, W. Malaysia, 28.6.1992)	-	-	-	+	+	-	-	+	+	-	-	+	+
S. penniger (Hook.) Holtt. (Umi Kalsom 270, Fraser's Hill, Pahang, W. Malaysia, 19.8.1991)	-	-	-	-	+	-	+	-	+	-	-	-	-
S. larutensis (Bedd.) C. Chr. (Nancy Jacob 19, Genting Sempah, Pahang, W.Malaysia, 23.7.1991)	-	-	-	-	+	-	-	-	+	-	-	-	-
Group B:													
S. norisii (Rosenst.) Holtt. (Nancy Jacob 10, Gunung Ulu Kali, Pahang, W. Malaysia, 28.6.1991)	-	-	-	-	-	-	-	-	-	-	-	-	-
S. peltochlamys (C. Chr.) Holtt. (Umi Kalsom 283, Cameron Highland, Pahang, W. Malaysia, 19.8.1991)	-	-	-	-	-	-	-	-	-	-	-	-	-
S. pterosporus (v. A. v. R.) Holtt. (Nancy Jacob 13, Genting Sempah, Pahang, W. Malaysia, 23.7.1991)	-	-	-	-	-	-	-	-	-	-	-	-	-

Key: Qu-3-gal=Quercetin-3-galactoside, Qu-3-glu=Quercetin-3-glucoside, Km-3-rha=Kaempferol-3-rhamnoside, Km-3-gal= Kaempferol-3-galactoside, Km-3-glu= Kaempferol-3- glucoside, SCH=Schaftoside, ISCH=Isoschaftoside, Isorham-3-glu=Isorhamnetin-3-glucoside. Ap=Apigenin, Km=Kaempferol, Qu=Quercetin,Ap-7-glu= Apigenin-7-glucoside they are therefore chemical substances which can be considered to provide useful systematic characters. Giannasi and Mickel (1979) have shown a correlation between flavonoid distribution and spore morphology in the closely related genera, *Hemionitis* and *Gymnopteris.* Species from both genera, which have crested spore morphology, produce kaempferol and quercetin 3-glycosidess, whereas species with tuberculate spores produce only quercetin 3,4diglycosides. Thus, the spore morphology and flavonoid data suggest that *Hemionitis* and *Gymnopteris* should be regarded as a single genus, *Hemionitis.* The flavonoid complement of *Loxsoma* and *Loxsomopsis* in the Loxsomaceae, reported by Markham and Given (Markham and Given, 1979), indicates that the two genera are closely related and that Loxsomaceae may not be closely related to the Hymenophyllaceae or the Cyatheaceae.

Analysis of the flavonoid composition of four varieties of *Dicranopteris* also support their morphological differences (Umi Kalsom, 1995). *D. linearis* var. *alternans* is characterized by the presence of quercetin 3-methyl ether-7-glucoside, quercetin 3-rutinoside and kaempferol 4'arabinosylglucoside, whereas *D. linearis* var. *subpectinata* contains apigenin 7-rhamnoside instead. In *D. linearis* var. *linearis,* both kaempferol 3-rhamnoside and luteolin 7-glucoside are found, but so far, *D. linearis* var. *montana* has been shown to contain only luteolin 7-glucoside.

Flavonoid patterns can be very useful in identifying the parentage of hybrids and hybridogenic species of ferns. This is because the hybrids show the patterns of both parents added together. Examples of these additive patterns have been reported by Harborne and coworkers (1973). This work established the identity of the specific compounds described in the classic hybrid study of Smith and Levin (1963). In 1980, Conant and Cooper-Driver demonstrated the existence, in Peurto Rico, of a swarm of fertile hybrids of the tree ferns *Alsophila bryophyla, A. dryopteroides* and *Nephelea protoricensis*, based on morphological and flavonoid characteristics. Again, the flavonoid pattern shown by the individual species is additive in the hybrids. It appears that the additive flavonoid pattern in proposed hybrids can be very useful in determining parental species.

The usefulness of flavonoid data in fern systematic has thus been established. Investigations using flavonoids directed towards solving known taxonomic problems and a comprehensive study of each of the fern genera would be productive.

Bioactivity of Ferns

It has been observed that pteridophytes which constitute ferns and fern allies are not infected by microbial pathogen. This may be one of the important factors for the evolutionary success of pteridophytes and the fact that, they survived for more than 350 million years (Sharma and Vyas, 1985). However, not many reports are available on the biological activity of ferns, yet the ethnobotanical importance of these plants have been investigated and studied by various authors. Malaysian ferns for example, are of great medicinal importance and are used by tribal and local people as remedy for various ailments (Burkill, 1966; Aziz Bidin, 1987; Kamaruddin Mat Saleh and Latif, 2000; Razali Jaman and Umi Kalsom, 2010c).

Antibiotic activity in the extracts of 114 species of pteridophytes has been studied. The plants were extracted in water, methanol, 70% ethanol, acetone and ether and assayed against 3 gram-positive and five gram-negative bacteria and three fungal plant pathogens. Sixty-seven ferns and 6 fern allies, representing 64% of the samples examined were found to be antibiotically active (Banerjee and Sen, 1980). Antifungal activity of flavonoids isolated from the leaves of the vegetable fern *Stenochlaena palustris* towards three pathogenic fungi, *Aspergillus fumigates, Guignardia mangifera* and *Ganoderma boninense,* have been evaluated. Fungicidal activity against these three fungi were observed at 800μg/ml for both flavonoids isokaempferide 7-*O*-glucoside and rhamnocitrin 3-*O*-glucoside (Umi Kalsom et al., 1999). The effects of isolated flavonoid components from the leaves of some medicinal ferns have also been evaluated against fetal rat liver (FRL 19) tumour cells (Umi Kalsom et al., 1995). It was found that at a concentration of 1.0 μg/ml, flavonoid kaempferol 3-*O*-rutinoside, kaempferol 3-*O*-glucoside and quercetin 3-*O*-glucoside inhibited FRL 19 tumour cell multiplication (**Figure 25**).

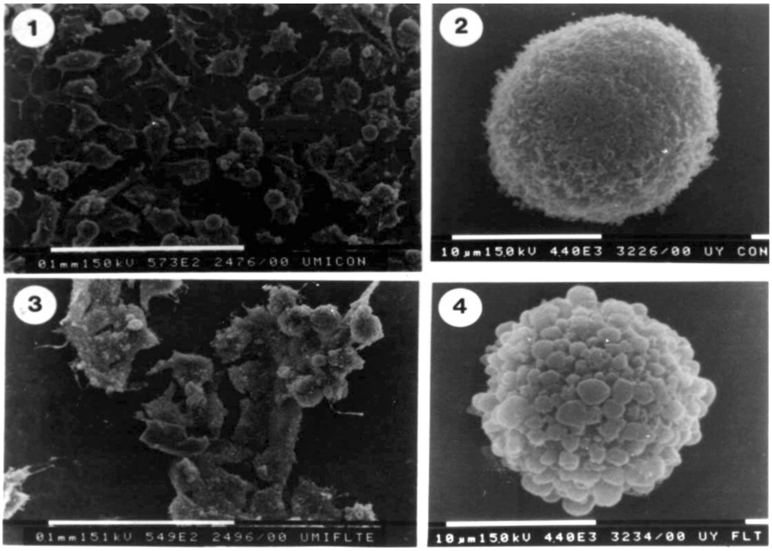


Figure 25 Morphology of FRL 19 control and treated FRL 19 tumour cells. **Figs. 1-2:** FRL 19 control with hairy surface; **Figs. 3-4:** Treated FRL 19 tumour cells with rugulose surface (Source: Umi Kalsom et al., 1995)

Kaempferol 3-*O*-rutinoside was isolated from *Diplazium esculentum* and *D. asperum.* Quercertin 3-*O*-glucoside was found in the leaves of *D. esculentum* and *Pteridium aquilinum*. Further, *P. aquilinum* also produced kaempferol 3-*O*-glucoside. The results of these studies provide useful scientific evidence on antifungal and antitumour properties and flavonoid contents of traditional medicinal ferns.

Chang and coworkers (2007) evaluated antioxidant activity of six medicinal ferns, *Drynaria fortunei, Pseudodrynaria cornans, Davallia divaricata, Davallia mariesii, Davallia solida* and *Humata griffithiana*. These ferns are used as “Gusuibu” or “Shibu” in Taiwan. Rhizomes of *Drynaria fortunei, Pseudodrynaria cornans, Davallia divaricata, Davallia mariesii, Davallia solida* and *Humata griffithiana* have been claimed to cure physique ache, inflammation, cancer, ageing, blood stasis and bone injuries. Both ethanol and aqueous extracts of these six ferns were characterized for their antioxidant and polyphenol content. The results have shown that most of the samples in aqueous extracts had higher antioxidant potencies and polyphenol contents than the ethanol extracts. This observation is in conformity with an earlier report, which observed that the antioxidant activities of more-polar solvent extracts (butanol and water extracts) exceeded those of non-polar solvent extracts (hexane and ethyl acetate extracts). The much higher antioxidant activity of the water extracts of “Gusuibu” preparations indicates that these medicinal ferns may be most effective when taken with water.

Khan and Omoloso (2008) analysed the antibacterial and antifungal activities of the medicinal fern *Angiopteris evecta.* The leaves, stem bark, stem heart wood, root and tubers of *A. evecta* were extracted successively with petroleum ether, dichloromethane, ethyl acetate, butanol and methanol. They found that all the fractions exhibited a wider spectrum of antibacterial activity. The dichloromethane and ethyl acetate fractions of the leaves and stem bark were particularly good and were the only fractions which exhibited antifungal activity. All fractions of the tuber, with the exception of petroleum ether, exhibited very good antibacterial activity. Recently, Parihar and coworkers (2010) studied *in vitro* antibacterial activity of twelve species of ferns against *Agrobacterium tumefaciens* (MTCC No. 431), *Escherichia coli* (MTCC No. 443), *Salmonella arizonae* (MTCC No. 660), *Salmonella typhii* (MTCC No. 734) and *Staphylococcus aureus* (MTCC No. 96). They found that nearly all the fern extracts show inhibitory effects against the selected bacterial strains and that some of the extracts were more competent than the selected antibiotic. They concluded that antibacterial activity of root extracts of these ferns and their active constituents would be helpful in treating various kinds of diseases. They also suggested that these findings could be further enhanced through *in vivo* studies and isolation and characterization of active constituents for human health.

How and coworkers (2010) evaluated antioxidant, anticancer and antibacterial activity from the leaves of medicinal fern *Blechnum orientale.* Results of the study have shown that ethyl acetate, butanol and water fractions possessed strong antioxidant and cytotoxic activity towards the human cancer cell HT-29. The three extracts were also effective against all Gram-positive bacteria tested: *Bacillus cereus, Micrococcus luteus,* methicilin-susceptible *Staphylococcus aureus* (MSSA), methicilin-resistant *Staphylococcus aureus* (MRSA) and *Staphylococcus epidermidis*. Phytochemical analysis of the leaves of *Blechnum orientale* revealed the presence of flavonoids in the active fractions. This finding corroborates an early study (Umi Kalsom, 1994b) that reported derivatives of flavones (luteolin, apigenin, acacetin and genkwanin) and flavonols (kaempferol, quercetin and isorhamnetin) in this fern. These flavonoids have been found to possess antioxidant, antitumour, and antimicrobial properties in previous studies (Cushnie and Lamb, 2005; Lin et al., 2008; Lopez-Lazaro, 2009; Kale *et al.,* 2008). These results also indicate the ethnomedicinal importance of the fern *Blechnum orientale* and its active constituents, which have potential to be used as antioxidant agent for colon cancer therapy and for treatment of MRSA infections and other MSSA or Gram-positive bacterial infectious diseases. Crude extracts and its interactions with different active fractions of the plants are needed to explore the exact mechanism of interaction among the active phyto-constituents.

CONCLUSION

Ferns remain very much understudied considering their prevalence, diversity and biological activities. Their ecology has not been studied much although they can be important elements in many communities, particularly at the gametophyte stage. However, the chemistry and economic value of many ferns have been studied comprehensively. A large number are considered to be highly prized as foliage ornamentals, both indoors or outdoors. It has been stated that most of the nursery supplies for their economic use as ornamentals, foods, medicinal and structure materials are from collections from wild populations and individuals from forests. Continuous deforestration and harvesting of timber-sized individuals and associated activities such as burning, tourism development and frequent landslides that bring about ecological disequilibrium threaten the survival of wild fern species. Most fern species live in a wide variety of habitats, from remote mountain elevation, to dry desert rock faces to bodies of water, and being shade and moisture-loving, grow in the interiors of forests. Ferns in general may be thought of as largely being specialists in marginal habitats, often succeeding in places where various environmental factors limit the success of flowering plants. There are four particular types of habitats where ferns are found: moist, shady forests; crevices in rock faces, especially when sheltered from full sun; acid wetlands including bogs and swamps; and tropical trees, where many species are epiphytes. Any disturbance of vegetation leads to the destruction of ferns. In certain forests the pteridophytes have been completely eradicated due to the destruction of forests to make way for crop cultivation. Therefore, it is concluded that though exploitation of fern taxa for scientific documentation and their economic value is necessary, it is also necessary that steps be taken for their conservation in botanical gardens in different parts of the country before many become endangered or permanently extinct. Moreover a large number of the Malaysian fern flora is endemic to the country. Of the approximately 640 fern species recorded from Peninsular Malaysia, 43 are endemic. Families with the highest number of threatened species ranked critically endangered (CR), endangered (EN) and vulnerable (VU) are Schizaeaceae (57%) and Grammitidaceae (50%). Grammitidaceae has, in addition, two extinct species; *Radiogrammitis pseudoxiphopteris* and *Xiphopterella gracilis*, both of which were endemic to Peninsular Malaysia. Hence special attention needs to be given to conservation activities. Any disturbance inflicted on ferns is sure to affect the biological equilibrium of the forest ecosystem. Thus, it is necessary that the individual States fully enforce the protective status of totally protected areas. This includes self-imposed regulations to not further convert forested areas for other land-use. Moreover, the habitats of species found in unprotected forests should be subject to protection. Apart from conserving ferns *in situ,* certain threatened species should be conserved *ex situ,* by cultivating and propagating them in gardens and green houses at different altitudinal levels with a view to re-establishing them in the wild.

Although field investigation is still important to locate the more obscure and less known species, to understand habitat specificity and morphological variations; it is also important that field botanists avoid ruthless collection of rare species and ensure that they leave the bulk of the plants to continue to grow and reproduce in their natural habitats. "The Conservation on Biological Diversity" Agreement signed by the heads of over 150 nations during the UN conference on environment and development held at Rio de Janeiro in June 1992 appreciates the need for habitat conservation. The major objective of the convention is the conservation of biological diversity and the sustainable use of its components for the benefit of present and future generations.

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BIOGRAPHY

Umi Kalsom Yusuf was born in 1957 in Sepang, Selangor. After completing her sixth form education in Aminuddin Baki, Kuala Lumpur, she pursued her tertiary education at Universiti Kebangsaan Malaysia and obtained an honours degree in Botany in 1982. She received her Doctor of Philosophy qualifications in Botany from the University of Reading, England in 1987.

Her academic career began in 1982 as a tutor at the UPM Sarawak Campus, Semenggok, Sarawak. She was appointed as a lecturer at the Department of Biology, UPM, Serdang in 1987, after she obtained her Doctor of Philosophy qualifications. She was promoted to Associate Professor in 1996 and to full Professor status in 2008. She served as the Head, Laboratory of Biodiversity and Conservation at the Rain orest Academy in 2002 and currently serves as the Head of the Biology Department, Faculty of Science.

In research, Umi Kalsom has been actively involved in fern biochemical systematics and biodiversity, collaborating with researchers locally and abroad. Todate, she has more than 240 scientific publications to her credit, of which over 90 articles are in refereed journals, book chapters and one book. Her research findings have also been presented at conferences, symposia and seminars, both abroad and locally. At the international level, she is a contributor to the *Plant Resources of South-East Asia* project. She is also a contributor to the *Flora of Peninsular Malaysia* projects. Being an academician, she has been teaching undergraduate and postgraduate students in her specialty areas of plant biodiversity, plant anatomy and plant chemotaxonomy. She is also actively involved in research supervision of graduate students pursuing their MSc and PhD degrees. She has also served as reviewer of articles to numerous international scientific journals. Umi Kalsom is also active in several local and international professional bodies. She has served as a member of the Botanical Linnaean Society of London, Phytochemical Society of Europe, assistant secretary of Malaysian Ecological Society (1991-1993), treasurer of Malaysian Ecological Society (1993-1995) and vice president of Malaysian Applied Biology (2007-2010).

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