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Phytogeographical analysis of the pteridophytes of some randomly selected areas of the world.

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ABSTRACT: Distributional problems of the *Pteridophyta* in the selected areas of the world were studied.

KEYWORDS: *Pteridophyta*, phytogeography, world.

Introduction

The paper attempts to give a phytogeographical analysis of the pteridophyte floras of various randomly selected areas of the world. There are some considerable obstacles to this type of research, mainly of nomenclatural and taxonomic nature to overcome. For instance a species may be regarded as endemic in one area, but it may appear under a different name in another, while later research may establish identity of the two (paper endemics, Storrigal), also, as happened recently with *Asplenium uhligii* Hieron., when this east and west African species was found to extend to southern Africa. In this context major disjunctions may also be mentioned, such as the so far unexplained disjunctive occurrence of *Asplenium platyneuron* (L.) Oakes in eastern North America and in South Africa. Are there any future discoveries of this fern to be expected, which may throw light on this peculiar distribution pattern? Recent cytological investigations by WAGNER and JOHNSON (1981) and CRIST and FARRAR (1983) seem to point to a genetical solution of the problem. Notwithstanding these difficulties the author attempts in this paper to clarify some distributional problems of the Pteridophyta. The uncertainty about a generally accepted subdivision of the plant kingdoms and provinces and the difference of resulting maps called for a decision on which to accept. The author has used here a suitable subdivision of his own (Fig. 1).

Method

In view of the author's knowledge of the African fern floras and of the literature he had originally selected a number of African regions for his study, but was able to extend the scope beyond this continent as some modern floras of other areas could be included. The following alphabetic list gives selected regions and of the research works involved:

Angola (SCHELPE 1977)
Australia (JONES and CLEMESHA 1984)
Central Europe (DOSTÁL et al. 1984)
Flora Zambesiaca area (SCHELPE 1970)
French tropical Africa (TARDIEU-BLOT 1953)
Jamaica (PROCTOR 1985)
Madagascar (TARDIEU-BLOT 1951, 1952, 1958, 1960, 1971)
Malaya (HOLTTUM 1966)
Mozambique (SCHELPE 1979)
New Zealand (CROOKES 1963, BROWNSEY and SMITH-DODSWORTH 1989)
Southern Africa (JACOBSEN 1983, SCHELPE and ANTHONY 1986, BURROWS and BURROWS 1990)
West Tropical Africa (ALSTON 1969)
Later addition: Guadeloupe (PROCTOR 1977)

For comparison a similar study was carried out for the genera of the Phanerogamae, using DYER (1976)

In each area the individual species were sorted into their corresponding distributional regions, such as South African, East African, West African or widespread throughout Africa ("African") or Afro-Madagascan etc. Those of equal distribution were counted and their percentage against the total number of species in the area were calculated. The results were summarized on Tab. 1.

The distributional regions were then combined into four major phytogeographical categories:

1. Endemic species (E)
2. Species ranging into adjacent areas (RNC)
3. Species that have a wider, but more or less continuous distribution, collectively called "of wider distribution" (WOD)
4. Species that are of wide, but scattered distribution or which occur disjunct, collectively called "widely distributed or disjunct" (WD)

These are demonstrated on Fig.'s 11, 12 and 13.

A slightly different procedure was adopted in the construction of Fig. 2, where in all cases five categories for each area were separated. In Jamaica for instance the few species of the northern USA (3) and temperate South America (14) were separated as TeAm (meaning temperate America). In Central Europe species occurring in the Near East, India and East Asia were separated from the Eurasian and northern circumhemispheral species, representing 6.3% vs. a remainder of 31.6%. In southern Africa the temperate elements were separated from the tropical African ones, resulting in two fractions of 8.45% and 16.55%, respectively. In all other African countries the purely African elements were separated from the Afro-Madagascan elements. In the case of Madagascar the African and western palaeotropic species are shown separately, while in Malaya Indo-Asian and Australo-Polynesian species were kept apart. In Australia and New Zealand, finally, it was decided to show Austral and subantarctic elements (14.6% and 4.2% respectively) separately from the West-palaeotropic elements. The subdivisions are thus also shown on the maps Figs. 3-10.

In all these instances the author came to the conclusion that on tables and diagrams the four-category system should be preferred in order to avoid confusion by a fifth line or a fifth symbol. All cases mentioned above were therefore re-combined for the remainder of the discussion as shown on tables 1 and 2 and on figures 11, 12 and 13. Some of the studied African areas were excluded from the construction of maps, as their phytogeographical structures are similar to each other, to avoid repetition.

The relationship to the geographical position was demonstrated on a longitudinal and a latitudinal graph (Fig. 11), using the calculated percentages of the four categories. A similar graph (Fig. 12) was designed to show the relationship of the percentage figures to the area of the various regions. Fig. 13 shows this without the disturbing fluctuating figures for the endemic species.

In the tables, maps and graphs it became necessary to use a number of abbreviations. They are listed alphabetically as follows:

Afr = species occurring throughout Africa
Afr-As = species of Africa extending into Asia
Afr-In = species of Africa extending to India
Afr-Madag = species occurring throughout Africa and Madagascar including the Mascarene and Comoro Islands
Afr-Madag-As = species occurring throughout Africa and Madagascar, the Mascarenes and Comoros and parts of Asia
Ang = species of Angola
Antil = species of the Antilles
As = species occurring in parts of the Asian continent
Au = species of Australia
Au-As = species of Australia, New Guinea and southeastern Indonesia
Austr = species of the temperate (austral) southern hemisphere
CAm = species of the central American countries
Centr S-Am = species of central South America
CEu = species of Central Europe, sensu Hegi (1974)
CP = species of the temperate areas of both hemispheres
Cosm = cosmopolitan species
Disj = widely disjunct species
E = endemic species
Eu-Med-Mac = species of Europe, the Mediterranean region and the Canary, Madeira and the Azores
Euras = species of Europe Russia and temperate northern Asia

Euras-Med = species of Eurasia and the Mediterranean region
FlZam = species of the Flora Zambesiaca area
FrAfr = species of the former French West and Equatorial Africa
Guad = species of Guadeloupe
In-As = species of India and other portions of Asia
Indochin = species of Burma, Thailand, Laos, Cambodia and Vietnam
Indones = species of Indonesia and the Philippines
Introd = introduced or alien species
Jam = species of Jamaica
Mal = species of Malaya
Masc = species of the Mascarene, Comoro and Seychelle Islands
Med = species occurring in the area around the Mediterranean
Med&NCP = species of the Mediterranean and the temperate northern circumpolar regions
Moz = species of Mozambique
N.C. = species of New Caledonia
NCP = species of the temperate regions of the northern hemisphere, barring the Mediterranean area
N.G. = species of Papua-New Guinea and Vanuatu
N-SAm = species of northern South America
N-USA = species of the temperate areas of the United States of America
NW-Eu = species of northwestern Europe
NZ = species of New Zealand
Cr-In-EAs = species of countries of the Near East, India and East-Asia
OWD = species of wider distribution
Paltr = species confined to the tropics of the Old World
Pantr = species occurring throughout the tropics
Pol = species occurring on any of the Polynesian Islands
RNC = species ranging into neighbouring or adjacent countries
Sbt = species occurring on any of the islands south of 350 Lat. S and/or in southernmost Chile
SE-As = species of southeastern Asia
S, E or W-Afr = species occurring in either southern, eastern or western Africa, but not throughout Africa
S-Eu-Med-Mac = species of southern Europe, the countries surrounding the Mediterranean and on the Macaronesian islands (Canary, Madeira or the Azores)
S-Afr = species of southern Africa
S-USA = species of the semi-tropical states of the United States of America
TeAm = species of temperate America
Te-SAm = species of Argentina and Chile
tpAfr = species considered to occur only in temperate parts of South Africa and in some African Highlands
TrAm = species of tropical America
TropAfr = species of tropical Africa
W-Afr = tropical West Africa

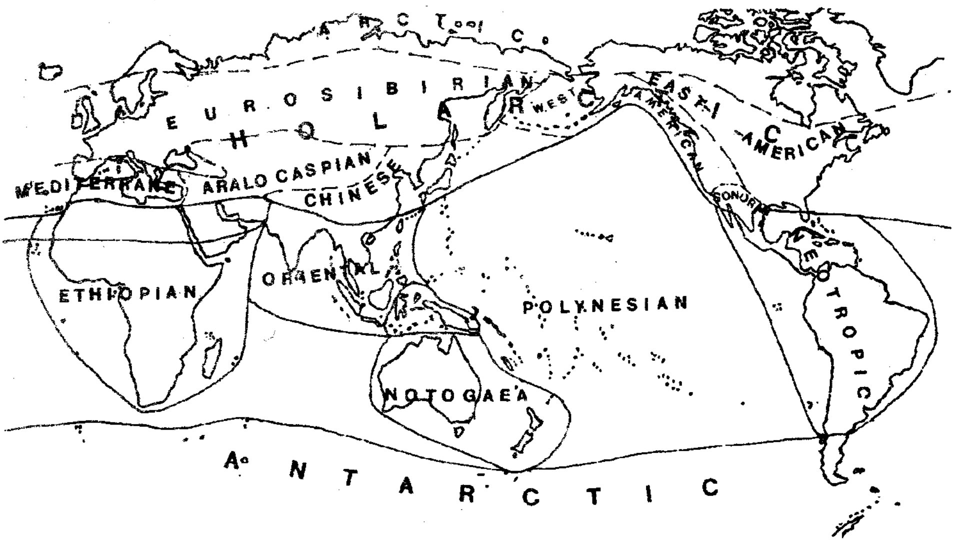


Fig. 1. Phytogeographic subdivision of the world as accepted in this paper.

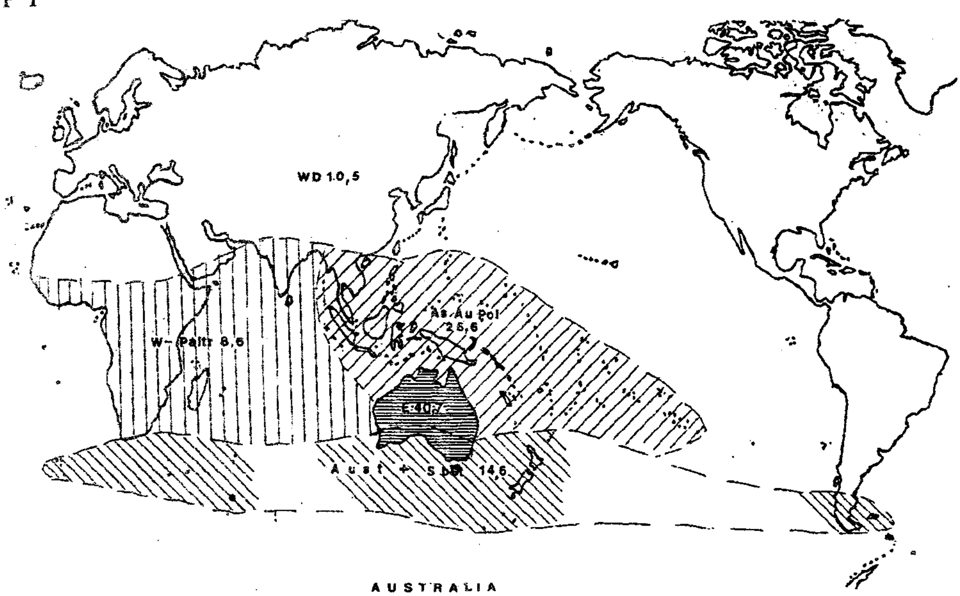


Fig. 3. Phytogeographical analysis of the pteridophytes of Australia.

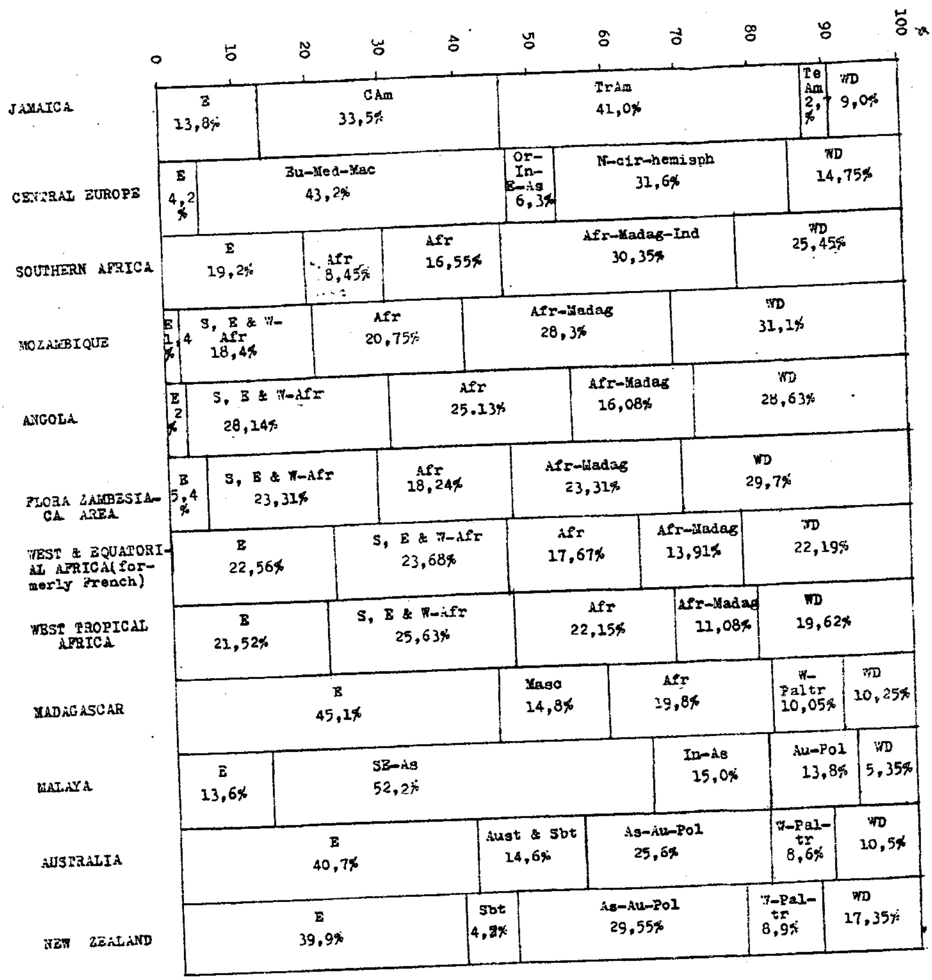


Fig. 2. Phytogeographical analysis of randomly selected areas of the world.

WD = widely distributed or disjunct species
W-Eu = species of western Europe
W-Paltr = species of the western part of the tropics of the Old World

Results

On the whole it was found that the grouping of the figures into four categories gave quite a good impression of the phytogeographical structure of the selected areas. Tab. 1 and especially Tab. 2 reveal that the figures for endemic species fluctuate in wide limits, from as low as 1.41% in Mozambique to enormous 45.1% in Madagascar. The figures for species extending into adjacent areas seem to have a tendency to fall between 20% and 30% (especially in the African areas) with only two exceptions in Central Europe (43.2%) and Malaya (52.2%). Within the species of wider distribution the concentration lies between 30% and 45%, with only two deviations, viz. New Zealand at 13.1% and Australia at 13.8%. The figures for the widely distributed or disjunct species fluctuate between 10% and 30%, with only minor deviations in the African areas in the 20-30% range, while all other areas have lower percentages. The reasons for the differences will now be discussed in more detail. They can usually be ascribed to the geographical positions of the areas in question, to a lesser extent to climatic conditions.

a) Endemics

The above rule is particularly evident within the endemic species. Here is not the place to embark on a discussion of the many problems of isolation and, as in our instance, island biogeography. With regard to *Pteridophyta* the normal amount of endemic species seems to lie around 20% in West, Central and southern Africa on account of their respective larger areas, enhanced in southern Africa by the unusually large number of xerophytic endemics in the southwestern and northwestern Cape and in Namibia. Abnormally low are the figures for the areas to the north of southern Africa, i.e. Angola, Mozambique, the Flora Zambesiaca area (Zambia, Zimbabwe, Mozambique and Botswana), countries which are not isolated and which allowed for a high degree of migration into neighbouring areas to the north and south at one time (VAN ZINDEREN-BAKKER 1960, 1962). At present migration towards the south appears not very feasible in view of the climatically much drier interspaced valleys of the Zambesi, Limpopo and Kunene Rivers, aggravated in the latter case, at least for mesophytic species, by the hostile climates of Namibia and Botswana.

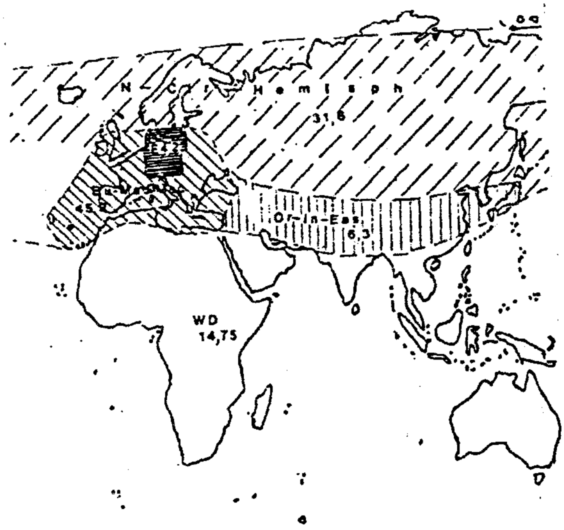


Fig. 4. Phytogeographical analysis of the pteridophytes of Central Europe.

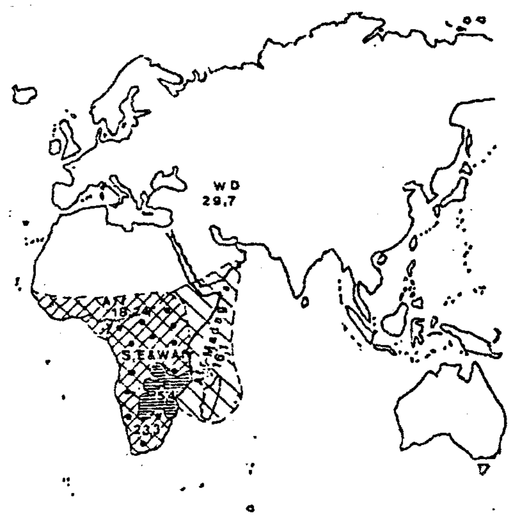


Fig. 5. Phytogeographical analysis of the pteridophytes of the Flora Zambesiaca area.

The percentage of endemics of islands in the neighbourhood of other islands or of continents and of the narrow isthmus of the Malay Peninsula seems to lie in the vicinity of 12-14%. In the cases selected here all have tropical climate with ample annual rainfall and therefore a luxurious fern flora (Guadeloupe 289 species, Malaya 486 and Jamaica even 636 species and varieties). In all instances there is strong evidence of migration to neighbouring islands or along the peninsula into adjacent areas.

A completely different picture is presented by the isolated large islands Madagascar, Australia and New Zealand. In all three the percentage of endemics is very large indeed. The pteridophyte floras are here quite varied. Madagascar has a total of 607 species and varieties, Australia has 383 and New Zealand 213. The former contains 1.58 times more species than the much larger Australia. The discrepancy seems to be due to the geographical position of Madagascar, where tropical and temperate African elements and Indo-Malaysian elements are mixed to a large extent, creating an abnormally rich fern flora. Prevailing southeasterly to easterly winds have obviously assisted largely in the transport of spores of Indo-Malaysian species. The flora of New Zealand, on the other hand, is already reduced due to a considerably cooler climate. However the number of endemic species is unusually large. In Australia and New Zealand as parts of the old Gondwanaland, the assumption is justified that most of the species are of palaeo-endemic nature and that isolation due to continental drift during the late Jurassic period gave rise to a rich endemic flora. Madagascar however was still connected with the African continent until the Miocene period and here one is more inclined to think in terms of neo-endemism. In the end, of course, this is rather irrelevant as all species have been once neo-endemic, then palaeo-endemic and ultimately will become extinct (RICHARDSON 1978).

b) Species ranging to adjacent areas

It is surprising that the percentage figures within the African areas show little variation, with Mozambique the lowest at 18.4% and Angola at 28.1% the highest. The former has strong links to South and East Africa with a very small contribution of West African species. The latter has a low percentage of South and East African elements, as migration was obviously impeded due to arid conditions immediately to the south and southeast. The flora however has a strong proportion (17.59%) of West African material. The same applies naturally to French West and Equatorial Africa and West tropical Africa; their partly even coincide in their areas.

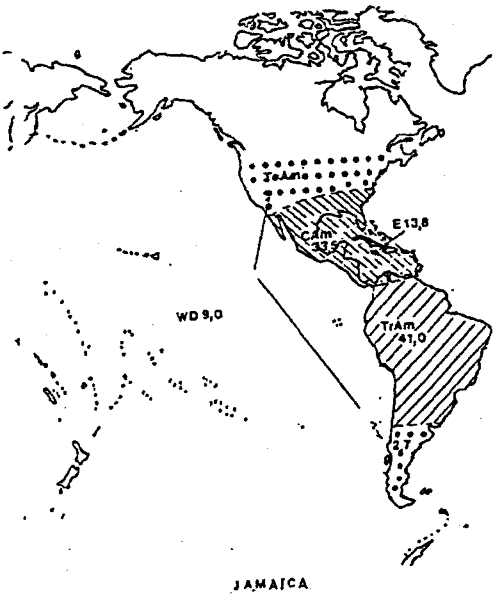


Fig. 6. Phytogeographical analysis of the pteridophytes of Jamaica.

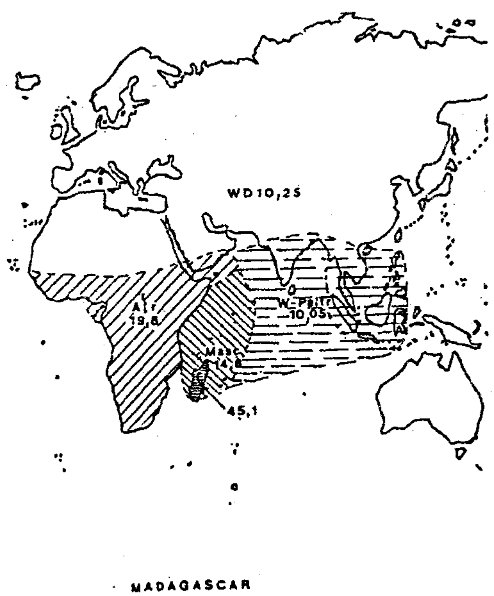


Fig. 7. Phytogeographical analysis of the pteridophytes of Madagascar.

The Flora Zambesiaca area (Fig. 5) has understandably strong connections with South and East Africa, as has southern Africa (Fig. 10) to the tropical areas.

Migration of tropical elements southwards was indeed strong as shown by JACOBSEN (1983). Madagascar (Fig. 7) has an unusually low percentage of species (14.8%) which it shares with its immediate neighbours, i.e. the Mascarene, Comoran and Seychelle Islands. This is attributed to the small area presented by these islands, which in their individual floras show a sharp reduction in the number of species. Thus the total for Reunion is 220 against Madagascar's 607 species.

Australia's (Fig. 3) figure of 25.6% is coincidentally within the range of the African countries and is composed of almost equal parts of Austral, Australasian and Polynesian elements with a minor portion of south-Polynesian species.

The islands of Jamaica (Fig. 6) and Guadeloupe were unfortunately selected in the same geographical region and are therefore similar in their phytogeographical structure with percentages between 33.5% and 30.8% respectively. Migration from these tropical and fern-rich areas to the neighbouring Antillean islands was strong at practically 21% as well as that to the Central American mainland and to the subtropical southeastern United States (in Guadeloupe at 7.27% to CAm and 2.77% to N-USA and about 6% in Jamaica in both cases).

The high percentages of species ranging to neighbouring areas in Central Europe (Fig. 4) and Malaya (Fig. 8) are due to the geographical position in both instances. The former is in the centre of Europe where migration from the west, south and southeast has been pronounced. In Malaya, a small tropical area with a luxurious fern flora and a relatively typical amount of endemics, the links to the floras of the neighbouring areas to the north and southeast is very strong and the number of species which is shared in the two areas is practically identical (26% in both cases). Further spreading towards the northwest and north was hampered by high mountain ranges and towards the southeast by insular isolation and increasing distance, and by climatic changes as well.

c) Species of wider distribution

This is a somewhat heterogenous category, on the whole embracing those areas which are more remote from the area under discussion, but still within feasible migration limits. In the cases of Australia and New Zealand (Fig. 9) however a mixture of what had to be called the subantarctic elements and the western portion of the palaeotropics, i.e. the Indonesian Archipelago, southeastern Asia, India, Madagascar and the

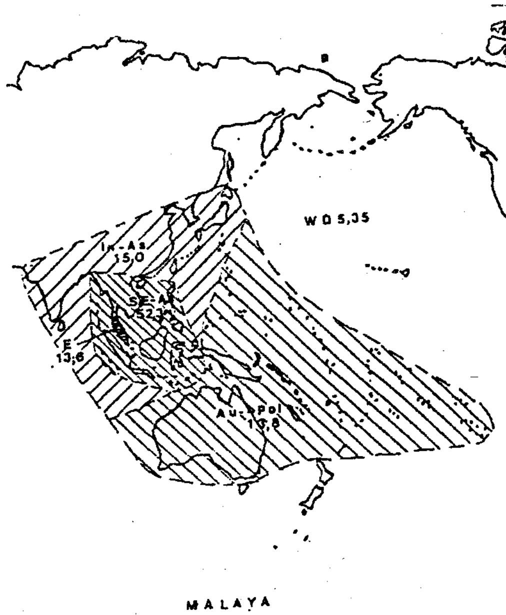


Fig. 8. Phytogeographical analysis of the pteridophytes of Malaya.

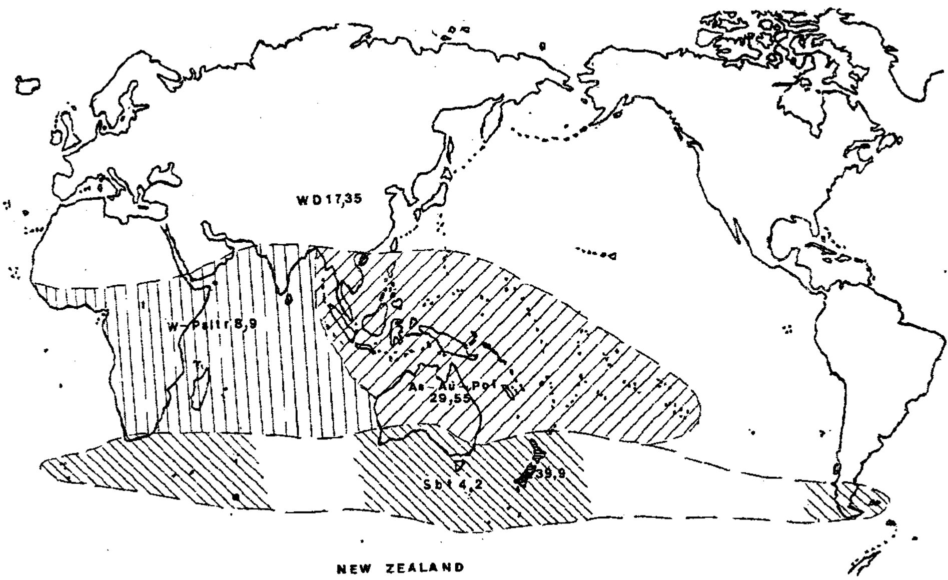


Fig. 9. Phytogeographical analysis of the pteridophytes of New Zealand.

African region, had to be included. In each instant the west paleotropic elements are more prominent than the subantarctic ones but percentages are low in both (13.8% and 13.1%, respectively). In the remainder of the areas, the lowest figures occur in Malaya (29.8%), where the reasons for the reduction are thought to have been caused by mountain ranges in the north and northwest. A similar low figure is recorded for Madagascar (29.9%), but this is even lower due to the unusually high figure for the endemics. In all African areas the Afro-Madagascan elements predominate, relatively, as expected, to the least extent in western Africa and most strongly in Mozambique (49.0%). The percentages for Central Europe, Jamaica and Guadeloupe are high, as migration into the eastern areas of Europe, Russia, temperate Asia and across the East-Asian landbridge to America was literally unhindered, so that the circumhemispheral elements amount to 22.6% of a total of 37.9% in this category. The two American islands have strong affinities to the tropical American regions, with which they share a great number of species, 129 in Guadeloupe and 210 in Jamaica.

d) Widely distributed or disjunct species

The category is mainly composed of species within remote areas, such as those in the palaeotropic, neotropic, pantropic regions, but also of cosmopolitan, widely disjunct and introduced species. Some typical examples for the last four are *Histiopteris incisa* (Thunb.) J. Sm. (pantropical), *Adiantum capillus-veneris* L. (cosmopolitan), *Asplenium platyneuron* (L.) Oakes (disjunct) and *Adiantum raddeanum* Presl (invader). In the case of Malaya even the Madagascan and African elements had to be somewhat illogically included and in the case of Jamaica the really remote areas of northern North America and the temperate parts of South America were incorporated in the category. The African areas rank first with figures in the 20-30% range, amongst which the palaeotropic elements are most prominent, but in southern Africa cosmopolitan and pantropic elements are quite numerous with 15 species each. The rest of the areas have low percentages, fluctuating between 9 and 15%, while Malaya due to its high species diversity, in the neighbouring category, is extremely poor in widely distributed species, the total, including African, Afro-Madagascan, pantropic and cosmopolitan species amounting to 5.35%.

e) Phytogeographical structure and geographical position (Fig. 11)

On Fig. 11 phytogeographical data of the different regions have been set in relation to their geographical positions in a west-east direction (top) and in a north-south direction (bottom). Most regions have large longitudinal and latitudinal dimensions. These are as follows:

Region	Longitude	Latitude
Angola	11°30'- 24°E	5° - 17°S
Australia	114° - 154°E	11° - 44°S
Central Europe	5° - 15°E	44° - 57°30'N
Flora Zambesiaca area	20° - 40°30'E	8° - 26°S
Guadeloupe	61° - 61°45'W	16° - 16°30'N
Jamaica	76° - 78°W	17°45'- 18°30'N
Madagascar	44° - 50°E	12° - 25°S
Malaya	100° - 104°E	1° - 6°N
Mozambique	30° - 40°30'E	11° - 26°S
New Zealand	167° - 179°E	35° - 47°S
Southern Africa	11°30'- 40°E	16° - 34°S
Tropical W-Africa	16°W - 15°E	2° - 14°N
French W-and Equat.Africa	16°W - 27°E	2° - 25°N

Corresponding percentage figures are given on Fig. 11 in the centre of east-west or north-south dimensions. Construction in this manner, however, is not very satisfactory. Australia for instance, with its large latitudinal range thus shows its centre line close to southern Africa, whereas one would have liked it closer to New Zealand. An attempt was made to construct average lines in the hope to reveal possible trends. This proved to be extremely difficult and in most instances merely illustrates what has been set out already in the foregoing discussion.

1. LONGITUDINAL SECTION.

The average line for the endemic species begins in the west with the Antillean islands and runs across the more or less same level to the African continent but then sinks to the very low figures of the sub-equatorial African states, although the figures for the tropical West African areas remain in the 20% region. The reasons were discussed in the chapter concerned with endemics, which is also the case of those of the three very high figures for Madagascar, Australia and New Zealand. The intervening very low figure for Malaya indicates that the very high values are exceptional and that probably an average for endemics will lie between 10 and 20%, but probably below 15%.

Line "RNC" with its plotting points represented by circles stands for the species ranging into adjacent areas. It begins in the west at a level just over 30%, but sinks over the African regions to between 20 and 30% and plunges finally in Mozambique and Madagascar even below 20%, but rises to the former level again over Australia and New Zealand. The peculiar low figures the eastern and southern African areas as well as Madagascar are due to the facility with which species under tropical conditions can spread over the whole of the Afro-Madagascan region. This distributional extension has been considered to belong to the category "of wider distribution". Indeed, the corresponding percentage figures (Fig. 11) (dots with included white asterisks) are high in these areas (Angola, Flora Zambesiaca, Mozambique). The exceptionally high figures for Central Europe and Malgassy have been discussed.

Figures for the species of wider distribution are on the whole between 35 and 40% in the western half of the globe, although a lower trend is noticeable over the larger African areas, which continues across to Madagascar, Malaya, Australia and New Zealand, where the lowest figure is reached at 13.1%. It appears that wider distribution of species in the eastern sector is hampered to a certain extent by high mountain ranges (Malaya) or by increasing isolation due to larger spaces between islands.

Line "WD", representing the widely distributed or disjunct species seems to be even around the 10-15% level on a worldwide basis, although all the African regions have slightly higher figures. The continent is situated between the New World and the eastern Palaeotropics and has been relatively strongly invaded by temperate northerly species, especially on the higher mountains of East- and West Africa. It has therefore an abnormally high rate of pantropic, neotropic and east palaeotropic, cosmopolitan, disjunct and introduced species, so that in all regions figures rise to between 20 and 30%. This is even more emphasized by the numerous phanerogamous genera of southern Africa where the percentage within the category reaches 36,62% and is mostly composed of pantropical (152), cosmopolitan (231) and introduced (190) genera (Tab. 1).

2. LATITUDINAL SECTION.

The endemic line "E" rises from low percentages in the north (4.2%) towards the tropics to more than 20% in the West African region, where a certain isolational effect by desert in the north and ocean in the south has caused an increase in endemic species. On the whole however the level in the equatorial region is around 15%, but decreases on the African continent towards the south to very low levels, where only southern Africa has higher figures. The reasons were discussed in previous chapters as were the exceptionally high figures of Madagascar, Australia and New Zealand.

The figures for the species ranging into adjacent areas sinks from the northern hemisphere towards the tropics, reaching the lowest values in the equatorial region and rising slowly again towards the south. Dense equatorial forests need not be as favourable to windblown spore distribution as the more windy temperate areas further to the north and south. In the African countries lower figures in this category are compensated by higher figures in the category "of wider distribution" as was already indicated in the discussion of the longitudinal section.

Line "OWD" (of wider distribution) runs on a more or less even level at just under 40%, but dips decidedly southwards towards southern Africa, Australia and New Zealand. Amongst other reasons already discussed, the inclusion of less numerous subantarctic species in this category in the far eastern regions contributes to the lower figures. The avarage of the widely distributed or disjunct species is fairly level at about 15%, although rising steadily towards the southern African states to between 20 and 30% (Mozambique). The reasons were discussed under the longitudinal section.

f) Phytogeographical data in relation to area (Fig's 12 and 13)

Fig. 12 was designed to investigate whether there is any relationship between the area of the regions and their phytogeographical structure. The sizes of the areas are shown on Tab. 2 in km². These are plotted using a logarithmic scale on Fig. 12 and 13. The former includes the strongly varying percentage figures of the endemic species. Fig. 13 excludes these species, setting the sum of the remaining three categories equal to 100%. This is as follows:

Region	RNC No.	RNC %	OWR No.	OWR %	WD No.	WD %	Total No.	Total %
Ang	56	28.72	82	42.05	57	29.23	195	99.97
Au	134	59.03	53	23.35	40	17.62	227	100.00
CEu	82	45.05	72	39.56	28	15.38	182	99.99
FlZam	69	24.64	123	43.93	88	31.43	280	100.00
Fr Afr	63	30.58	84	40.78	59	28.64	206	100.00
Guad	89	35.04	129	50.79	36	14.17	254	100.00
Jam	213	40.11	261	49.15	57	10.73	531	99.99
Madag	90	27.03	181	54.35	62	18.62	333	100.00
Mal	254	60.48	140	33.33	26	6.19	420	100.00
Moz	39	18.66	104	49.76	66	31.58	209	100.00
N Z	63	49.22	28	21.88	37	28.91	128	100.01
St Afr	65	30.95	79	37.62	66	31.43	210	100.00
W+Afr	81	32.66	105	42.34	62	25.00	248	100.00
Genera	621	38.81	184	11.50	795	49.69	1600	100.00

This procedure eliminates the bias created by those areas where the number of endemic species are exceptionally high.

Fig. 12 reveals that the number of endemic species drops from very large areas steadily to a minimum in areas of between 2.6 and 0.7 mill. km^2 but that there is a definite percentage increase in insular areas. The decrease is caused by the concentration of those areas of medium size which are portions of continental land masses, in which migration into and from adjacent regions, even of continental dimensions (category "of wider distribution") is much facilitated. Although this has not been proved yet, a similar behaviour can be forecasted when other inter-American or inter-Asiatic regions will be investigated.

Species ranging into adjacent areas should now be expected to follow a complimentary reciprocal course. That this is not so, is due to the interference by the category "of wider distribution", the delimitation of which is after all a rather flexible concept, especially where diverging phytogeographical units as subantarctic elements and west-palaeotropic elements are included in the category. This was done in the cases of Australia and New Zealand. The two categories seem to intergrade also to a certain extent in Africa, where a clear-cut separation between them is difficult. As shown on figure 12 there is a sinking trend of the line of the species which extend into neighbourly countries until the 0.7 km^2 mark, from where a rapid ascent within areas of 100,000-260,000 km^2 takes place (Malaya has 130,000 km^2 and about 60% of all species in this category). The line moves then to the still relatively high figures of 30-40% in the very small areas.

The figures for the category of wider distribution show on the whole a steady rising tendency until the 0.7 mill. km^2 mark, where with descending size by reasons set out above a complimentary reciprocal dip over the New Zealand-Malaya area sets in, which however rises just as rapidly towards the smaller Antillean areas to terminate at about 50% on Fig. 13 or at over 40% on Fig. 12. If the two latter categories are taken together an average line would connect the intercrossings and would thus reveal a steadily rising trend from large areas towards smaller ones, in other words an increasing trend towards more pronounced migration as the areas decrease in size. The widely distributed or disjunct species seem to become a little more prominent towards the African regions at about 30% for reasons set out in chapter e). They decrease from areas of less than 1 mill. km^2 to about 10% in the small areas. The unusually high figure for New Zealand of 17.4% is due to a high proportion of introduced species.

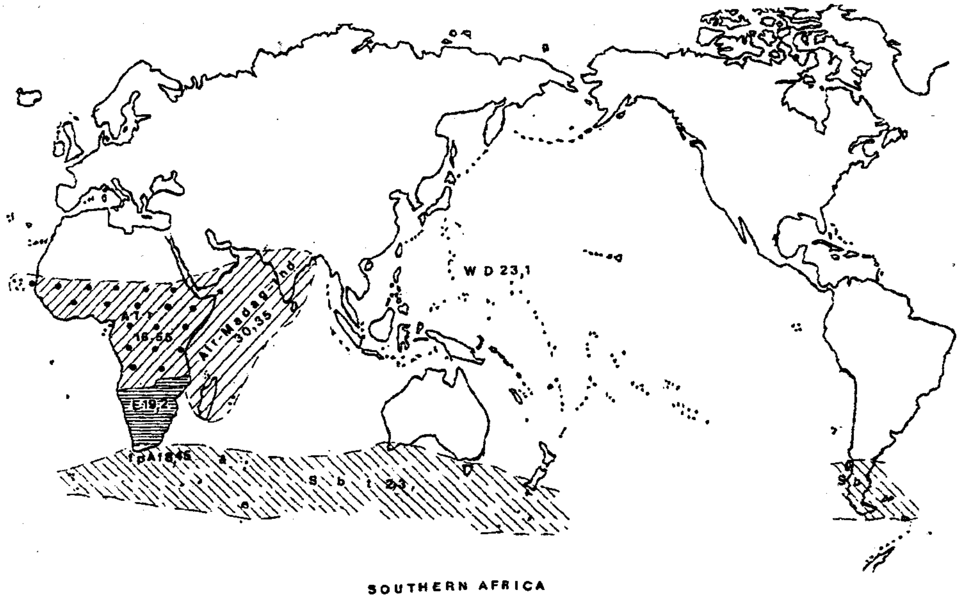


Fig. 10. Phytogeographical analysis of the pteridophytes of Southern Africa.

Conclusions

This paper does not contain any new contribution to the distribution of *Pteridophyta* in the various areas discussed, but bases entirely on the published works. It has, however, opened up a more or less statistical line of research. It has shown that fern distribution is not a simple function of size or position of area against number of species, following the well known parabolic curve, but that many factors are involved. It is known that endemic plants are more numerous in the southern hemisphere than in the northern (STOTT 1981), but are the reasons merely historical or climatic as it might appear? Is the paucity of endemic species in the sub-equatorial countries of Africa, Angola, Zambia, Mozambique and Zimbabwe due to any of these? The facility of an area to harbour a luxurious or poor fern flora is indeed mainly a question of climatic conditions and in many cases also of historic events (ice ages, tectonic phenomena etc).

It has been shown in this paper that the opportunity to migrate or better said spread, is of greatest importance. Isolation is naturally the reason for the number of endemics within a flora. The most isolated archipelago in the world, the Hawaiian Islands, are a flagrant example, where more than 90% of its plant species and 69% of its pteridophytes are endemic (WAGNER 1988). But even large areas in less isolated positions such as Australia and Madagascar have an unusually large number of endemics. This cannot be only due to isolation. There are certainly other factors contributing, many of

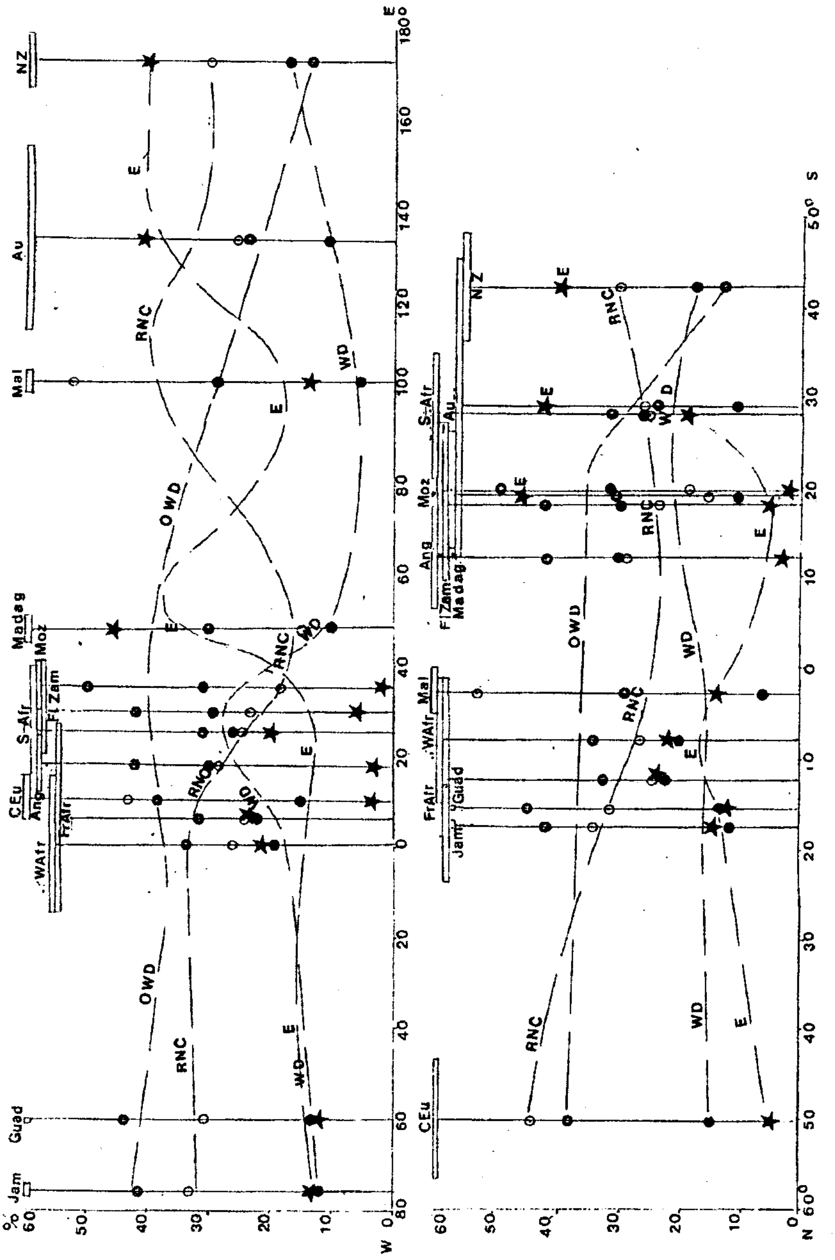
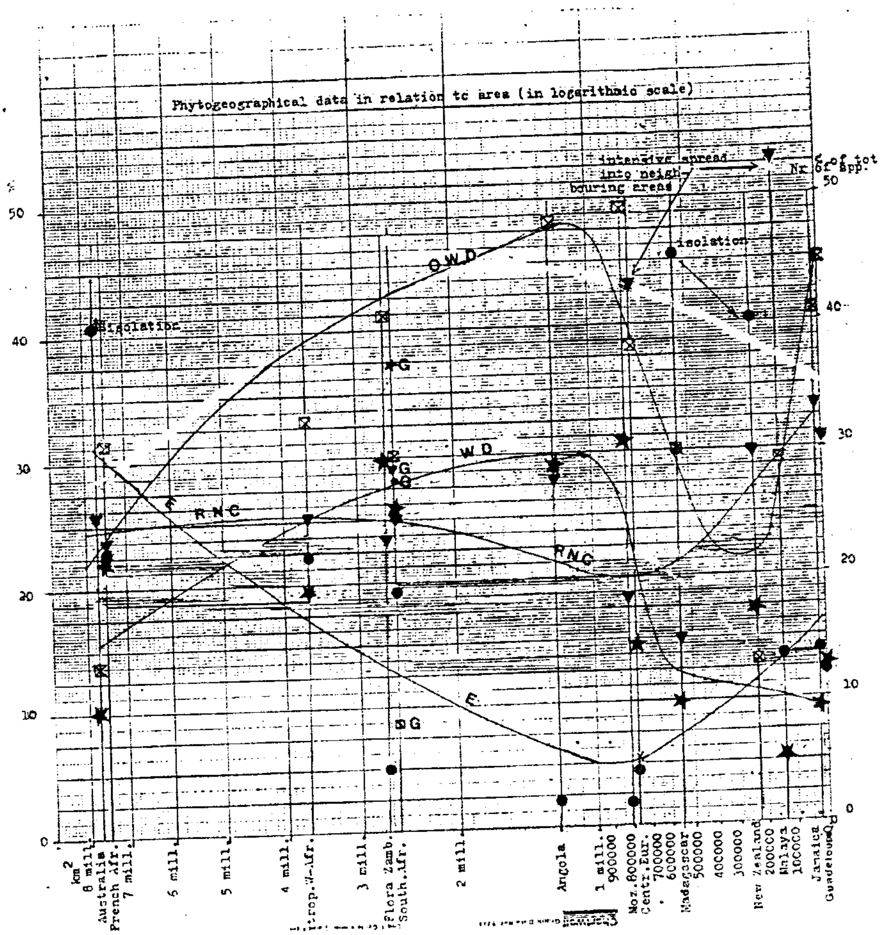


Fig. 11. Phytogeographical data of the Pteridophyta of various regions in relation to their geographical position. Above: in East-West direction, below: in North-South direction.



EXPLANATION

- ● E Endemic species
- ▼ RNC Species ranging to neighbouring regions
- ☒ OWD Species of wider distribution
- ✶ WDD Widely distributed or disjunct species
- ●G, ▼G, ☒G, ✶G: Genera of Southern African flowering plants

Fig. 12. Phytogeographical data of the Pteridophyta of various regions in relation to area. Areas plotted on a logarithmic scale.

them palaeobotanical, but also geographic, as the position between two or more floral kingdoms or provinces. Examples such as Madagascar, Taiwan or Venezuela come to mind (JACOBSEN unpublished paper, KORNAS 1979, TRYON and TRYON 1982). However much has been written on endemism and disjunctions, the problems cannot all be tackled in one paper.

Emphasis in this paper has been laid on a numerical investigation of fern distribution, on the number of endemics, species of medium - sized ranges and widely distributed or disjunct species within a number of areas It is found that in general terms species of wider distribution are most numerous, but that in certain areas the distribution reached merely into the neighbouring areas as for instance in Malaya and in Central Europe. In this respect it must be realised that a clear-cut delimitation of the two categories, neighbourly or spreading into adjacent areas and those of wider distribution is not easy and must be regarded as flexible. Species which are widely distributed or disjunct, to which all phytogeographical terms such as palaeotropic, neotropic, pantropic, cosmopolitan and even introduced species belong, constitute generally not more than 10-15% of the individual pteridophyte floras.

This paper cannot in any way claim to be exhaustive, but has indicated that by evaluation of available data some phytogeographical and/or distributional problems can become somewhat clearer. Further research along these lines would be welcome.

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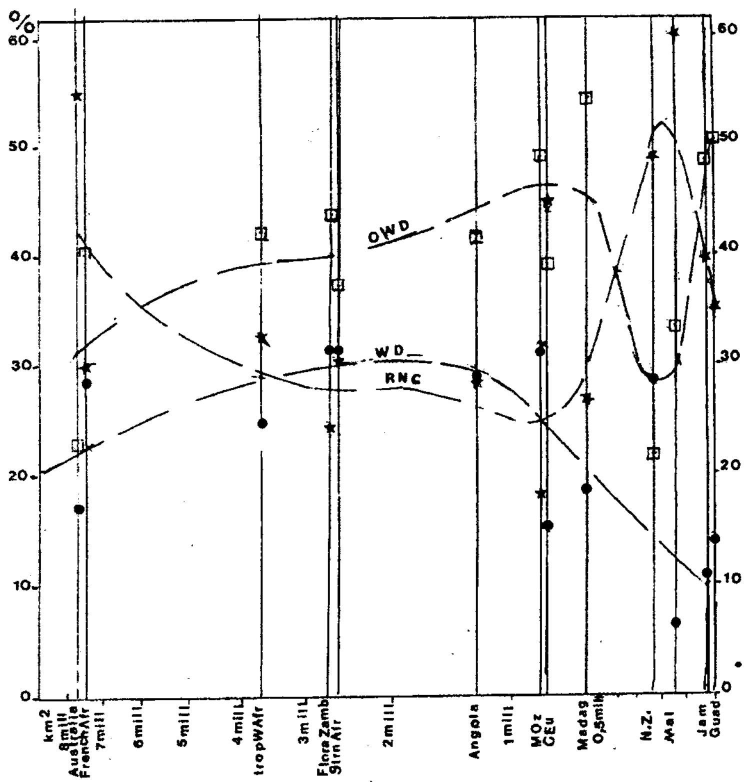

Fig. 13 Phytogeographical data of the Pteridophyta of various regions in relation to area, but endemic species excluded and the sum of the remaining three categories calculated to 100%.

ANGOLA

Endemic No %	S-Afr No %	E-Afr No %	W-Afr No %	Afr No %	Afr-Madag No %	Paltr No %	Neotr No %	Pantr No %	Cosm No %	Disj No %	Introd No %	Total No %
4 2.01	9 4.52	12 6.03	35 17.59	50 25.13	32 16.08	21 10.55	4 2.01	17 8.54	5 2.51	9 4.52	1 0.50	199 99.99
	56 28.14 % S,E,W-Afr.			82 48.21 % Afr-Madag				57 28.63 % Widely distributed				

AUSTRALIA

Endemic No %	Austr No %	Au-As No %	Pol No %	Austr-Pol No %	Sbt No %	W-Paltr No %	Neotr No %	Pantr No %	Cosm No %		Introd No %	Total No %
156 40.7	36 9.40	40 10.40	39 10.20	19 5.00	20 5.20	33 8.60	4 1.05	19 5.0	8 2.1	.	9 2.35	383 100.0
	134 25.6 % Austr, Au, As & Pol				53 13.8 % Sbt & W-Paltr.			40 10.5 % Widely distributed				

CENTRAL EUROPE

Endemic No %	NW-Eu No %	W-Eu No %	S-Eu Med Mac No %	Or-In-EAs Ind-As No %	Euras No %	NCP No %	Cosm No %	Disj No %	Introd No %	Total No %
8 4.2	15 7.9	37 19.5	30 15.8	12 6.3	17 8.95	43 22.6	7 3.7	15 7.9	6 3.15	190 100.0
	82 43.2 % Eu - Med - Mac			72 37.9 % As, Euras, NCP			28 14.75 % Widely distributed			

FLORA ZAMBESIACA AREA

Endemic No %	S-Afr No %	E-Afr No %	W-Afr No %	Afr No %	Afr-Madag No %	Paltr No %	Neotr No %	Pantr No %	Cosm No %	Disj No %	Introd No %	Total No %
16 5.4	30 10.13	29 9.80	10 3.38	54 18.24	69 23.31	31 10.47	13 4.39	16 5.4	11 3.72	13 4.39	4 1.35	296 99.98
	69 23.31 % S, E, W-Afr			123 41.55 % Afr-Madag				88 29.72 % Widely distributed				

FRENCH TROPICAL AFRICA

Endemic No %	S-Afr No %	E-Afr No %	W-Afr No %	Afr No %	Afr-Madag No %	Paltr No %	Neotr No %	Pantr No %	Cosm No %	Disj No %	Introd No %	Total No %
60 22.56	3 1.13	11 4.13	49 18.42	47 17.67	37 13.91	23 8.65	3 1.13	21 7.89	6 2.26	5 1.88	1 0.38	266 100.01
	63 23.68 % S, E, W-Afr			84 31.58 % Afr-Madag				59 22.19 % Widely distributed				

GUADELOUPE

Endemic No %	Antil No %	CAm No %	S-USA No %	Tr Am No %	Paltr No %	Pantr No %	Cosm No %	Disj No %	Introd No %	Total No %
35 12.1	60 20.7	21 7.27	8 2.77	129 44.64	12 4.15	16 5.54	1 0.35	4 1.38	3 1.04	289 100.0
	89 30.80 % CAm S-USA					36 12.46 % Widely distributed				

JAMAICA

Endemic No %	Antil No %	CAm No %	S-USA No %	N-Am No %	Central S-Am No %	N-USA No %	TeSam No %	Pantr No %	Cosm No %	Introd No %	Total No %
88 13.8	135 21.2	40 6.3	38 6.0	210 33.0	51 8.0	3 0.5	14 2.2	38 6.0	5 0.8	14 2.20	636 100.0
	213 33.5 % CAm, S-USA			261 41.0 % Tr Am				57 9.0 % Widely distributed			

Tab. 1. Phytogeographical analyses of the Pteridophyta of some randomly selected regions.

MADAGASCAR

Endemic	Masc	S & E-Afr	W-Afr	Afr	W-Paltr	Neotr	Pantr		Cosm	Disj	Introd	Total
No %	No %	No %	No %	No %	No %	No %	No %		No %	No %	No %	No %
274 45.1	90 14.8	46 7.6	11 1.8	63 10.4	61 10.05	14 2.30	21 3.50		10 1.65	16 2.60	1 0.20	607 100.0
		181 29.85 %				62 10.25 %						
		African Continent & W-Paltrop				Widely distributed						

MALAYA

Endemic	Indochin	Indones	Ind	China-Japan	N.G.	Au	Pol	Madag/Masc	Afr	Pantr	Cosm	Total
No %	No %	No %	No %	No %	No %	No %	No %	No %	No %	No %	No %	No %
66 13.6	126 25.9	128 26.3	43 8.8	30 6.20	28 5.80	14 2.90	25 5.10	11 2.30	8 1.65	5 1.00	2 0.40	486 99.95
	254 52.2 %		140 28.8 %					26 5.35 %				
	SE-As		Indo-Asian-Australo-Polynesian					Widely distributed				

MOZAMBIQUE

Endemic	S-Afr	E-Afr	W-Afr	Afr	Afr-Madag	Paltr	Neotr	Pantr	Cosm	Disj	Introd	Total
No %	No %	No %	No %	No %	No %	No %	No %	No %	No %	No %	No %	No %
3 1.41	15 7.08	21 9.90	3 1.41	44 20.75	60 28.30	26 12.26	9 4.24	14 6.60	7 3.30	7 3.30	3 1.41	212 99.96
	39 18.39 %			104 49.05 %		66 31.11 %						
	S, E and W-African			Afro-Madag		Widely distributed						

NEW ZEALAND

Endemic	Au-As-Pol	Pol	Sbt & S-Chile	W-Paltr	Neotr	Pantr	Cosm	Introd	Total
No %	No %	No %	No %	No %	No %	No %	No %	No %	No %
85 39.90	54 25.35	9 4.20	9 4.20	19 8.90	3 1.40	6 2.80	5 2.35	23 10.80	213 99.90
	63 29.55 %		28 13.10 %		37 17.35 %				
	Au - Pol		Sbt & W-Paltr		Widely distributed				

SOUTHERN AFRICA

Endemic	tpAfr	Trop Afr	Afr-Madag	Afr-In	Sbt	Paltr	Neotr	Pantr	Cosm	Disj	Introd	Total
No %	No %	No %	No %	No %	No %	No %	No %	No %	No %	No %	No %	No %
50 19.20	22 8.45	43 16.55	71 27.30	8 3.10	6 2.30	12 4.60	10 3.85	15 5.80	15 5.80	2 0.80	6 2.30	260 100.05
	65 25.0 %		79 30.35 %		66 25.45 %							
	Temperate & Tropical Africa		Afr-Madag-In		Widely distributed							

WEST TROPICAL AFRICA

Endemic	S-Afr	E-Afr	W-Afr	Afr	Afr-Madag	Paltr	Neotr	Pantr	Cosm	Disj	Introd	Total
No %	No %	No %	No %	No %	No %	No %	No %	No %	No %	No %	No %	No %
68 21.52	5 1.38	25 7.91	51 16.14	70 22.15	35 11.08	23 7.28	8 2.53	14 14.43	6 1.90	10 3.16	1 0.32	316 100.0
	81 25.63 %			105 33.23 %		62 19.62 %						
	S, E & W-Afr			Afr-Madag		Widely distributed						

FOR COMPARISON: FLOWERING PLANTS OF SOUTHERN AFRICA/ GENERA ONLY.

Endemic S-Africa	Endemic Namibia	Trop Afr	Afr-Madag	Afr-As	Euras/Med	NCP	Sbt	Neotr	Paltr	Pantr	Cosm	Introd	Total
No %	No %	No %	No %	No %	No %	No %	No %	No %	No %	No %	No %	No %	No %
522 24.05	78 3.59	393 18.11	84 3.87	144 6.64	98 4.52	30 1.38	56 2.58	91 4.19	101 4.65	152 7.0	231 10.64	190 8.76	2170 99.99
600 27.54 %		621 28.62 %			184 8.48 %			765 35.25 %					
Endemic		Afr-Madag-Asian			Med & CP			Widely distributed					

Tab. 1. (continued)

Region	Area km²	E	RNC		OWD		WD	
		%	%		%		%	
Australia	7682300	40.7	25.6	Au, Au-As, Pol	23.2	Sbt, W-Paltr.	10.5	Neotr, Pantr, Cosm, Introd
French Tropical Africa	7452688	22.6	23.7	S, E or W-Afr	31.6	Afr-Madag	22.2	Paltr, Neotr, Pantr, Cosm, Disj, Introd
West Tropical Africa	3676746	21.5	25.6	S, E or W-Afr	32.2	Afr-Madag	19.6	Paltr, Neotr, Pantr, Cosm, Disj, Introd
Flora Zambesiaca Area	2643236	5.4	23.3	S, E or W-Afr	41.6	Afr-Madag	29.7	Paltr, Neotr, Pantr, Cosm, Disj, Introd
Southern Africa	2578257	19.2	25.0	tpAfr & Trop Afr	30.4	Afr-Madag-In	25.5	Paltr, Neotr, Pantr, Cosm, Disj, Introd
Angola	1246700	2.0	28.1	S, E or W-Afr	41.2	Afr-Madag	28.6	Paltr, Neotr, Pantr, Cosm, Disj, Introd
Mozambique	799379	1.4	18.4	S, E or W-Afr	49.0	Afr-Madag	31.1	Paltr, Neotr, Pantr, Cosm, Disj, Introd
Central Europe	759930	4.2	43.2	Eur-Med-Mac	37.9	As, Euras, N-CP	14.8	Cosm, Disj, Introd
Madagascar	587041	45.1	14.8	Masc	29.9	Afr & W-Paltr	10.3	Neotr, Pantr, Cosm, Disj, Introd
New Zealand	268103	39.9	29.6	Au-As, Pol	13.1	Sbt & W-Paltr	17.4	Neotr, Pantr, Cosm, Introd
Malaya	133600	13.6	52.2	SE-As	28.8	In, As-Au-Pol	5.4	Madag/Masc, Afr, Pantr, Cosm
Jamaica	10991	13.8	33.5	Antil, C-Am, S-USA	41.0	Tr Am	11.7	N-USA, Te S-Am, Pantr, Cosm, Introd
Guadeloupe	1780	12.1	30.8	Antil, C-Am, S-USA	44.6	Tr Am	12.5	Paltr, Pantr, Cosm, Disj, Introd
Southern Africa: Genera of Phanerogams	2578257	27.6	28.6	Afr-Madag-As	8.5	CP	36.6	Paltr, Neotr, Pantr, Cosm, Introd

Tab. 2. Results of Tab. 1, combined into four categories and set in relation to area.

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