INVESTIGATION OF KERATINOPHILIC FUNGI FROM SOILS IN WESTERN AUSTRALIA A PRELIMINARY SURVEY

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Abstract

In order to determine which species of geophilic dermatophytes were present in Western Australian soils 299 samples were investigated. These samples were collected from a range of locations, 208 from towns throughout the state and 91 samples from the Perth Metropolitan area.

Most samples were collected from areas frequented by people and animals, such as home gardens, parks and animal yards.

Of the total 299 soils, 271 (90.6 %) yielded keratinophilic fungi. A total of 181 dermatophytes were isolated, and there were 205 isolations of other keratinophilic fungi.

Microsporum gypseum (30.7 %) was the most prevalent dermatophyte recovered from soil followed by *Microsporum cookei* (21.7 %) and then *Trichophyton ajelloi* (8.0 %). No other dermatophytes were recovered. *Chrysosporium indicum* was the most common of all the keratinophilic fungi and was isolated from 50.1 % of the samples. Mixed growth was obtained from 33.5 % of the soil samples.

Introduction

Keratinophilic fungi living in soil serve to break down any keratin containing wastes such as skin, hair, fur and feathers. These fungi therefore have a role in the breakdown of soil debris. Some keratinophilic fungi by way of this property are potentially pathogenic to man and animals and are known as dermatophytes; those found living in soil are termed geophilic dermatophytes.

In 1894 Sabouraud (23) made the suggestion that the dermatophytes may be soil saprophytes. However it was not until Vanbreuseghem (24), described a hair baiting technique for recovering these fungi from soil that mycologists in many parts of the world were able to investigate their soils in order to recover these fungi.

The only dermatophyte isolated consistently from the soil of different countries is *Microsporum gypseum*. Of the other keratinophilic fungi isolated frequently from soil *Trichophyton ajelloi* Georg *et al.* (15) and Presbury and Young (22) and *Microsporum cookei* Mariat and Tapia (16) and Frey (13), have only on very rare occasions been reported as the cause of infection. Ajello (2) suggested two possibilities for failure to isolate the common dermatophyte fungi from soil. 'Either these fungi have become so specialized in their growth requirements that they can survive and maintain themselves only on living animal hosts; or suitable techniques are lacking with which to detect and isolate them from their environment.' Whatever the reason for this failure there is still no proof that soil does actually provide an alternative habitat for the important pathogenic dermatophytes. Any reports of recovering these dermatophytes from soil seem to be chance isolations and do not afford proof of a constant infection source.

Surveys of soils in different parts of Australia show somewhat different patterns in the occurrence of keratinophilic fungi. Durie and Frey (12), examined soil samples from each Australian state including 48 samples from Western Australia. Their W.A. soils yielded few keratinophilic fungi; one isolate of *M. gypseum*, two of *T. ajelloi*, two of *T. terrestre*, two *Trichophyton species* and two *Chrysosporium species*. They isolated much the same species from each state and no *M. cookei* was recovered. The overall incidence of *M. gypseum* was 10.4 % which is low compared with recovery rate in this W.A. survey (30.7 %). *T. ajelloi* on the other hand had a similar recovery

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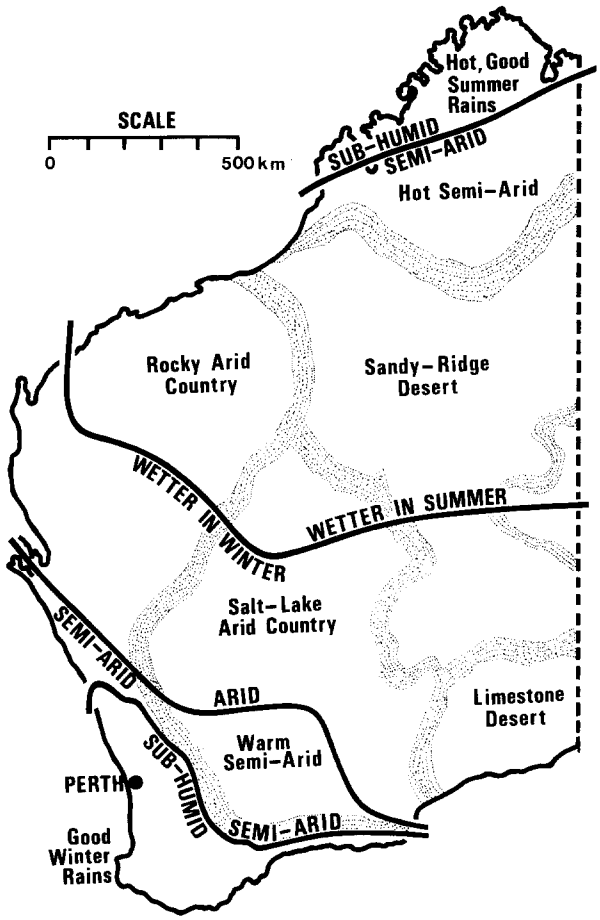

Fig. 1. Regional environments of Western Australia. Map by courtesy of J. Gentilli. Australian Climate Patterns 1972, Nelson Melbourne, and Western Landscapes 1979, University of Western Australia Press, Nedlands.

rate, 9.4 % in their survey and 8.0 % on this W.A. survey. They isolated *T. terrestre* from 2 samples of W.A. soil but although it was expressly looked for in this present survey it was not recovered. Donald and Brown (10), in South Australia recovered only *M. gypseum* and *T. ajelloi*. Dunne and Morahan (11), isolated a greater variety of species including *M. cookei* and their highest yield was of *Chrysosporium species* (102 isolates).

This present survey was undertaken as a preliminary investigation of the geophilic dermatophyte and other keratinophilic fungi in Western Australian soil, and to investigate this soil as a possible natural habitat for the pathogenic keratinophilic fungi. Because many authors have found that different soil conditions influence the distribution of keratinophilic fungi, some of these factors have also been examined. Individual biotypes are thought to play a part, and inhabited areas such as home gardens are usually considered a rich source of these fungi. Among the environmental factors thought to be important are the presence of organic matter, and the pH, temperature and moisture content of the soil.

Western Australia covers an area of 2,525,500 sq. kilometers and includes a range of climatic and soil types as can be seen in fig. 1. Much of the state is hot and dry, there are no high mountain ranges and no areas with winter snow. The soils generally have a small organic content mainly because large areas have sparse vegetation and all of the endemic trees and shrubs are evergreen. Even our best soils are low in organic matter when compared with Northern Hemisphere soils. Many areas of the state from Perth northwards, have maximum summer temperatures of 40 °C or more, and surface soil temperatures would be at least 10 °C above this temperature for great lengths of time in exposed areas. Mean highest solar radiation over 63 years for Perth in January is 62 °C, and the highest on record for Perth is 76 °C.

Information on surface soil temperatures for most of Western Australia is not available. However, in a study at Bakers Hill (72 kilometers east of Perth), on soil which was without any type of plant cover; when the air temperature was 40 °C the surface temperature of the soil reached 64 °C; and at a depth of 2 cm. it was 51 °C, (GB. Taylor, C.S.I.R.O., Perth, personal communication). Factors which significantly lower soil temperature are high moisture content and even a light vegetation cover. Soil colour and mineral composition also affect temperature.

Materials and methods

A total of 299 soil samples were collected mainly during the winter months of July and August from the 31 areas in the state of Western Australia depicted in figure 2. W.A. is divided into two almost equal halves, a northern half which is wetter in summer and a southern half which is wetter in winter (see figure 1.); areas north of this dividing line were therefore sampled during their dry season. The twenty eight locations selected in different suburbs of the Perth area, (shown in figure 3), were chosen to give a representative sample of different parts of the metropolitan area. The towns selected throughout Western Australia were generally those where we have a branch laboratory so that the laboratory staff could collect the soil samples

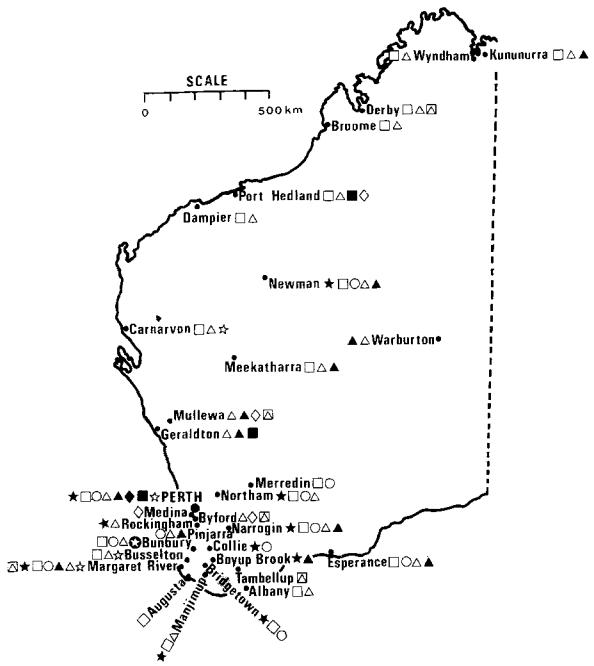

Fig. 2. Keratinophilic fungi isolated from different locations in Western Australia. Key to symbols.

Table 1. Summary of samples examined and species isolated.

Total soil samples	299	
Total fungal isolates	386	
Total soils from which keratinophilic fungi were isolated	271	(90.6%)
Samples lacking keratinophilic fungi	28	(9.4%)
Number of samples with more than one species	91	(33.5%)
SPECIES ISOLATED:		
Microsporum gypseum	92	(30.7%)
Microsporum cookei	65	(21.7%)
Trichophyton ajelloi	24	(8.0%)
Chrysosporium indicum	150	(50.1%)
Chrysosporium tropicum	27	(9.0%)
Chrysosporium asperatum	9	(3.0%)
Chrysosporium evolceanui	6	(2.0%)
Chrysosporium keratinophilum	1	(0.3%)
Verticillium chlamydosporium	4	(1.3%)
Verticillium psalliotae	7	(2.3%)
Malbranchea state of Uncinocarpus reesii	1	(0.3%)

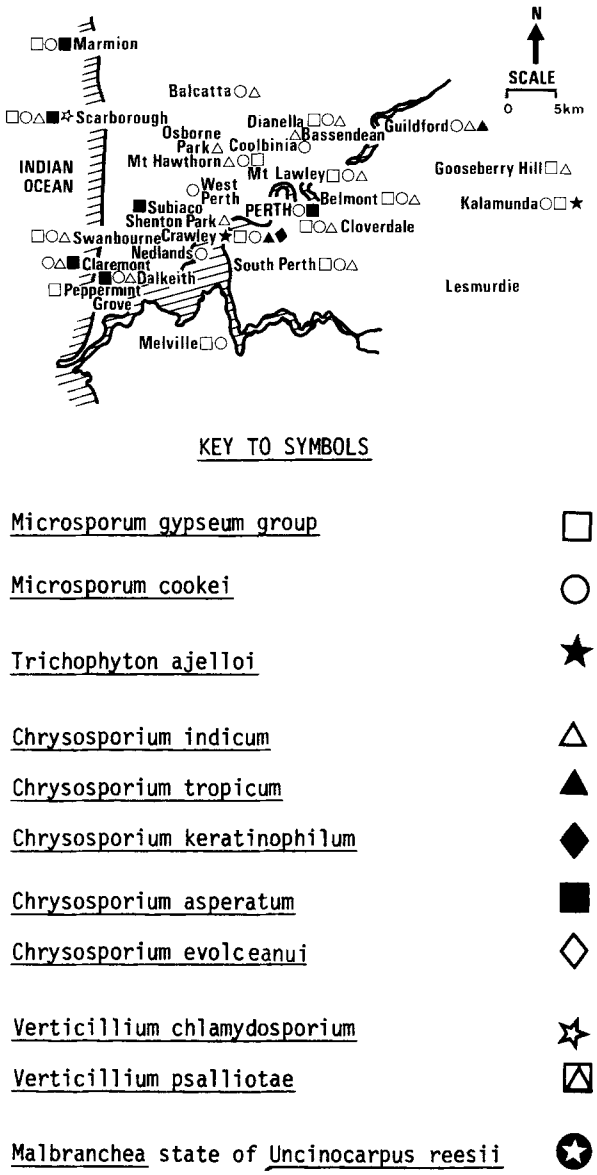

Fig. 3. Keratinophilic fungi isolated from different locations in the Perth Metropolitan area.

required. The aim was to obtain a reasonable spread of different climate and soil types throughout the state. The north of the state is sparsely populated so fewer localities were investigated in this area than the more densely populated south west corner.

The technique employed in this study was that described by Vanbreuseghem (24) and Ajello (1). The instruction given for collecting samples was to scoop surface soil (the

top 2 cm), from areas likely to be rich in organic matter direct into 2 oz., wide necked plastic jars, label and despatch to Perth. Suggested areas for sampling were garden beds, stables and near houses, as areas with mammal contamination have been found in other parts of the world to give the best yield of keratinophilic fungi. Although this preliminary survey included some areas with little human or animal pollution the aim was really to find which keratinophilic fungi occur in the soils of this state.

A sterile petri dish was half-filled with soil from each sample. These were moistened with sterile distilled water and baited with short pieces (7-12 mm) of mixed sterile human hair and horse hair. Both of these types of hair proved to be a good source of keratin to use as bait for keratinophilic fungi. The samples were incubated at 25 °C, examined at weekly intervals for six weeks, then at approximately fortnightly intervals for 3 months. The soils were kept moist during this period. When the hairs had a good growth of fungus they were examined under the plate microscope to determine different types of growth. Some hairs were selected for direct microscopy and some were transferred to cycloheximide slopes to obtain pure cultures for identification.

The pH of each soil was tested; the system used was a simple accurate indicator technique using the C.S.I.R.O. Soil pH Test Kit supplied by Inocula Laboratories, Victoria, Australia. The pH is determined to the nearest half unit which is adequate for soil testing.

Table 2. Percentage of total samples in each area from which the different keratinophilic fungi were isolated.

Town	Number of Samples Examined	Number of Samples Positive	Number of Isolates	Microsporum gypseum	Microsporum cookei	Trichophyton ajelloi	Chrysosporium indicum	Chrysosporium tropicum	Chrysosporium evoleanui	Chrysosporium asperatum	Verticillium chlamydosporium	Verticillium psallotiae	Chrysosporium keratinophilum	Malbranchea state of Uncinocarpus reesii
1. Wyndham	7	4	4	42.8			14.3							
2. Kununurra	30	30	39	30.0			96.6	3.3						
3. Derby	15	15	22	60.0			80.0					6.6		
4. Broome	5	5	6	40.0			80.0							
5. Port Hedland	10	10	17	40.0			100.0		10.0	20.0				
6. Dampier	10	8	9	20.0			70.0							
7. Newman	10	9	12	10.0	10.0	20.0	70.0	10.0						
8. Warburton	13	13	14				46.0	61.5						
9. Meekatharra	11	9	12	9.0			63.6	36.3						
10. Mullewa	5	5	10				100.0	60.0	20.0			20.0		
11. Carnarvon	7	6	9	57.1			57.1				14.2			
12. Geraldton	5	4	5				40.0	40.0		20.0				
13. Perth Metro Area	91	80	121	31.8	52.7	8.8	27.4	3.3		6.6	1.1		1.1	
14. Bunbury	6	6	9	33.3	50.0		50.0							16.6
15. Busselton	8	8	10	50.0			62.5				12.5			
16. Margaret River	8	8	15	37.5	12.5	37.5	62.5	12.5			12.5	12.5		
17. Augusta	4	4	4	100.0										
18. Albany	3	3	3	66.6			33.3							
19. Esperance	8	8	12	62.5	25.0		50.0	12.5						
20. Merredin	4	3	4	66.6	66.6									
21. Northam	5	5	10	60.0	40.0	60.0	40.0							
22. Pinjarra	6	5	7		33.3		66.6	16.6						
23. Narrogin	6	6	8	16.6	33.3	16.6	50.0	16.6						
24. Collie	2	2	2		50.0	50.0								
25. Bridgetown	2	1	3	50.0	50.0	50.0								
26. Manjimup	3	3	4	33.3		33.3	66.6							
27. Rockingham	3	2	2			33.3	33.3							
28. Medina	3	1	1						33.3					
29. Byford	3	3	6				33.3		100.0			66.6		
30. Tambellup	3	2	2									66.6		
31. Boyup Brook	3	3	4			100.0		33.3						

Results of survey

Table 1 indicates the total number of samples examined, the number of soils which grew keratinophilic fungi and the species isolated.

Of the 299 soil samples examined 271 (90.6 %) grew keratinophilic fungi in culture. Compared with other soil surveys reported in the literature this appears to be a high isolation rate; but some reports are only concerned with dermatophytes. Some samples grew more than one fungus and a total of 386 isolates of keratinophilic fungi were recovered. Other fungi growing in the cultures but not actually growing on the hair bait were considered to be non-keratinophilic fungi and were not identified.

Among the five genera isolated, eleven species were identified (see table 1.). Species of *Microsporum* and *Chrysosporium* were the most common fungi in these samples. *C. indicum* and *M. gypseum* appear to occur throughout the state (see figure 2.), and were isolated from 50.1 % and 30.7 % of the soils respectively. *Chrysosporium* species are widespread in occurrence in Western Australia but most prevalent in the more arid regions, this applies particularly to *C. indicum* and *C. tropicum* (see table 2.). This table shows the total number of samples from each area that were examined and the percentage of this total comprised by each species isolated. Two fungi which occurred almost exclusively in the cooler, wetter, south west corner of the state are *M. cookei* and *T. ajelloi*. These species occur mainly in the sub-humid, good winter rain zone, depicted in figure 1.

Discussion

General

Microsporum gypseum proved to be ubiquitous in Western Australia and was isolated from most areas. It was present in a great range of climatic and soil types, 30.7 % of the samples examined yielded this fungus; it was recovered from hot arid areas with low rainfall and from soils with low organic content. In this survey *M. gypseum* gave indication of being able to tolerate a great range of conditions. Some difficulty was experienced in the identification of many of the strains isolated from these soils and they are here classified as *M. gypseum* group. Work is continuing on these strains as they are not typical of any of the species in this group and mating experiments on some of them have so far been unsuccessful. Phyllis M. Stockdale of the Commonwealth Mycological Institute (personal communication) has suggested that they be left as *M. gypseum* group until further work can be done on them. *Nannizzea gypsea* was isolated from seven soils.

Microsporum cookei was found mainly in the temperate south west corner of the state. It was common in the Perth metropolitan area both in coastal and inland suburbs. It was interesting to note its presence in 12 of the 15 samples collected from wild (native) animal pens in a Perth suburb; the pH of these soils ranged from 5.0 to 9.5. Many of the animals in these enclosures were carrying *M. cookei* in their coats. *M. cookei* was not isolated from any of the 18 samples collected at 6 different pig farms in the south west of the state where soils tended to be acid. Marples (17) in New Zealand found that *M. cookei* was

Table 3. Number of soil samples with more than one species. Numbers of each combination.

Combinations	Number of each Combination
M. gypseum; C. indicum	28
M. gypseum; M. cookei	13
M. gypseum; C. tropicum	2
M. gypseum; T. ajelloi	1
M. cookei; T. ajelloi	3
M. cookei; C. indicum	6
M. cookei; C. asperatum	1
T. ajelloi; C. tropicum	1
T. ajelloi; C. indicum	1
T. ajelloi; V. psalliotae	1
C. indicum; C. tropicum	6
C. indicum; C. evolceanui	1
C. indicum; V. psalliotae	1
C. indicum; V. chlamydosporium	3
C. tropicum; C. asperatum	1
C. evolceanui; V. psalliotae	1
M. gypseum; M. cookei; C. indicum	3
M. gypseum; M. cookei; T. ajelloi	5
M. gypseum; T. ajelloi; C. indicum	1
M. gypseum; M. cookei; C. asperatum	1
M. gypseum; M. cookei; C. tropicum	1
M. gypseum; C. indicum; C. asperatum	1
M. gypseum; C. indicum; C. tropicum	1
M. cookei; T. ajelloi; C. keratinophilum	1
M. cookei; C. indicum; C. tropicum	1
M. cookei; C. indicum; C. asperatum	1
C. indicum; C. tropicum; V. psalliotae	1
C. indicum; C. evolceanui; V. psalliotae	1
M. gypseum; M. cookei; T. ajelloi; C. tropicum	1
M. gypseum; C. indicum; C. asperatum; C.evolceanui	1
M.cookei; C.indicum; C.asperatum; V.chlamydosporium	1
TOTAL	91

M = Microsporum; T = Trichophyton; C = Chrysosporium; V = Verticillium

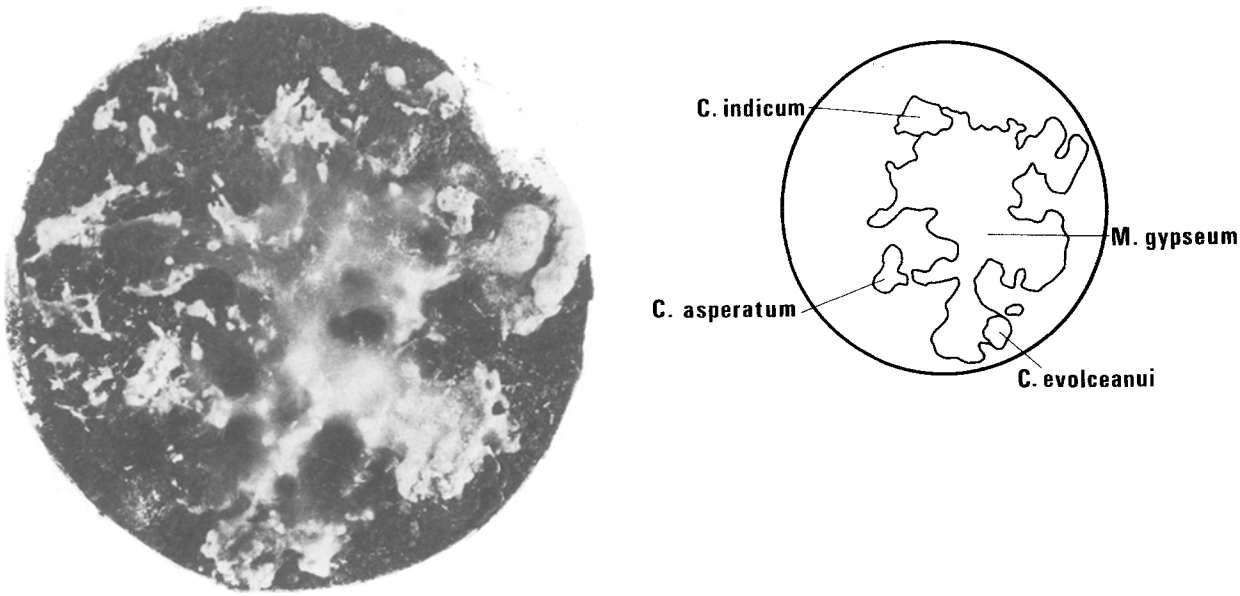

Fig. 4. Soil sample from Port Hedland showing a mixed growth with *Microsporum gypseum* predominating, and smaller growths of *Chrysosporium indicum*, *C. asperatum* and *C. evolceanui*.

closely associated with animal contaminated substrate. The south west areas have more moisture in the soil for longer periods of the year than other soils in the state and the soils are mainly sandy with some organic matter. There were some variations seen in the macroscopic appearance of these isolates, mainly in degree of red pigmentation; some had a pigment on the surface as well as the reverse of the colony and some were completely atypical dysgonic forms when first isolated. *Nannizzia cajetani*, the perfect state, was isolated from 14 soils.

Trichophyton ajelloi was found mainly in the south west of the state and was present in both the area where native animals were housed and also in soils from 3 of the 6 pig farms. In the Perth area only the soils from the animal enclosure and from the hillside suburb grew *T. ajelloi*. Palsson (21) in Sweden found this fungus preferred temperate regions but their temperate zones would be climatically very different to the south west corner of Western Australia. In W.A. it is obviously not simply the climatic zone which influences the presence or absence of this fungus. The cultural characteristics varied from one isolate to the next. They all had a very powdery dark buff tan surface but some strains had purple black pigment on reverse and some lacked pigment. Microscopically there was some variation from the long more slender spores to the shorter spores, somewhat resembling *Epidermophyton floccosum*. In some cases the direct microscopy from the soil had longer spores whereas the microscopy from the culture had the shorter spores similar to *E. floccosum*. *Arthroderma uncinatum*, the perfect state, was isolated from one specimen only.

Chrysosporium indicum was widespread throughout Western Australia and had the highest prevalence (50.1 %), of the keratinophilic fungi isolated. It seems to be able to grow in any type of soil and climate in W.A. and was prevalent in arid areas occurring in all soils examined from Geraldton northwards. There were 6 isolates which have been identified as nearest to *C. indicum* but the spores were slightly larger. Four of these were isolated in the Perth metropolitan area and two from the north west of the state.

Chrysosporium tropicum was isolated from 27 samples (9.0%), from quite a wide range of climate and soil types. Some of these strains (13 isolates) have been identified as nearest to *C. tropicum*, these strains came particularly from the Warburton district. Two of these strains were identified by L. Sigler, Alberta, Canada, as probably *C. tropicum*. Six other strains from this area were similar and not typical of *C. tropicum*, as the spores differ in size.

The prevalence of each of the remaining species is generally low, and none were isolated from more than 3.0 % of the total soil samples.

The perfect states of the three dermatophyte fungi were isolated from some soils, *Nannizzia gypsea* from seven, *N. cajetani* from fourteen and *Arthroderma uncinatum* once only. The asexual name has been retained in all the tables

Table 4. Keratinophilic fungi isolated from specific soil habitats in Western Australia.

Source of Soil Sample	Garden	Yard Home or Public	Paddock (Field)	Paddock (Animal Cow-Horse)	Animals (Pets)	Native Animal Enclosure	Bush	Roadside	River Bank	Sand Dunes	Pine Plantation	Pig Farm	Number Examined	Total Isolates
Total Samples Examined	98	81	6	10	17	15	26	5	9	3	11	18	299	
Samples Positive	90	76	5	9	16	14	25	5	7	2	8	14	271	
Percentage Positive	91.8	93.8	83.3	90.0	94.1	93.3	96.1	100	77.7	61.6	72.7	77.7	90.9	
SPECIES ISOLATED														
M. gypseum	39	21	1	4	7	5	10	1	2	1	1			92
M. cookei	37	4	2		3	12	3			1	3			65
T. ajelloi	5	2	1		3	6	1		1			5		24
C. indicum	42	62	2	5	13	0	7	3	5	2	4	4		150
C. tropicalis	1	15	1	1	1	2	3	1		1		1		27
C. asperatum	8				1									9
C. evolceanui	1	1										4		6
C. keratinophilum						1								1
V. chlamydosporium	1		1						1	1				4
V. psalliotae		2										5		7
Malbranchea state of Uncinocarpus reesii	1													1
TOTAL	135	107	8	10	28	26	24	5	9	6	8	19		386

M = Microsporum; T = Trichophyton; C = Chrysosporium; V = Verticillium

for uniformity. No typing of the *T. ajelloi* or *M. cookei* cultures has been attempted. Thirty-nine of the *M. gypseum* group which are atypical strains are proving difficult to type, and so far only one has been placed definitely as a + mating type.

From 91 soil samples more than one keratinophilic fungus was isolated, the most common combination being *M. gypseum* and *C. indicum* but there were 31 combinations in all (see table 3). On 18 occasions 3 different species were isolated and on 3 occasions 4 species. The occurrence of more than one fungus in a sample appears to be independent of pH, organic matter or any of the other environmental factors observed. Figure 4. shows a combination of four different keratinophilic fungi on one soil sample.

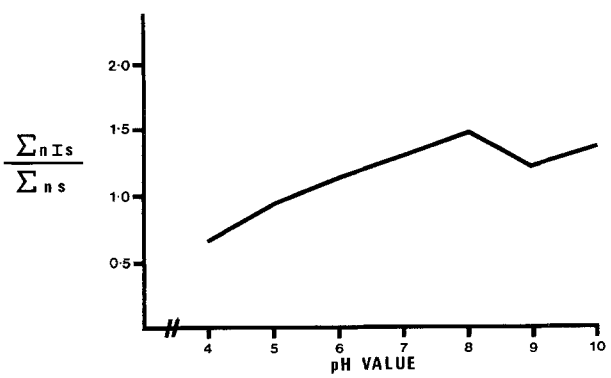

Fig. 5. Proportion of the total isolates at each pH value to the total soils at that value, by the pH scale.

The pig farm soils were investigated in an effort to isolate *M. nanum* but failed to yield this fungus. No *M. nanum* has been isolated from any pigs in Western Australia to this time. Similarly soils were collected from areas poulated by cats infected with *M. canis* to try and isolate this fungus. The soils were baited with cat fur as well as horse hair but the only fungus recovered was *M. gypseum*.

The pine plantation samples were examined in an effort to recover *T. terrestre* when all other sandy soil samples failed to yield this fungus. Balabanoff and Usunov (5) suggested that this fungus was isolated from coniferous leaves.

Environmental factors

a) Individual Biotypes

Local environmental conditions in areas from which the soils were collected are shown in table 4, together with the numbers of different species isolated from each type of environment. The majority of these sites are inhabited, and soils from garden areas have a higher degree of moisture at all times of the year and usually more organic matter. Some habitats had too few samples to give any information of prevalence but most localities yielded some keratinophilic fungi. The most ubiquitous species were found in most areas; 45.8% of the *T. ajelloi* isolates came from the native animal enclosure and the pig farms together, and *M. cookei* was common in the native animal enclosure, 18.4% of the isolates came from this area.

b) Effect of pH

Most of the soil samples examined in this survey were in the middle pH range, weakly acid to weakly alkaline, from pH 6 to 9. There were very few strongly acid or alkaline soils (see table 5.), none below pH 4 or above pH 10.

In the south west of Western Australia the soils were on average inclined to be slightly acid and those in the north slightly alkaline.

Blaschke-Hellmessen (6) and Bohme and Ziegler (7), found that very acid soils inhibit fungi even if organic matter is abundant and that weakly acid to weakly alkaline soils are optimal for keratinophilic fungi regardless of organic content. Muhammed and Lalji (19) found that in Kenyan soils keratinophilic fungi favoured acid conditions and site the prevalence of *M. gypseum* and *T. ajelloi* in these soils as examples.

Figure 5. plots the proportion of the total isolates at each pH value to the total soils at that value, by the pH scale. It indicates that a peak in this proportion is reached at pH 8, in weakly alkaline soils.

c) Effect of Organic Matter

There appears to be no doubt that soils containing a high proportion of organic matter are also rich in keratinophilic fungi in most parts of the world.

Table 5. Total number of soils at each pH value and the keratinophilic fungi isolated at each value.

pH Value	Total No. of Soils at each Value Σ n s	Microsporum gypseum	Microsporum cookei	Trichophyton ajelloi	Chrysosporium indicum	Chrysosporium tropicum	Chrysosporium asperatum	Chrysosporium evolceanui	Chrysosporium keratinophilum	Verticillium chlamydosporium	Verticillium psallotiae	Malbranchea state of Uncinocarpus reesii	Total Isolates at each Value Σ n Is
4	3	2											2
5	18	6	3	4	3						1		17
6	28	7	7	5	6		1	3			3		32
7	76	25	32	4	30	3	2	1			2		99
8	63	23	13	4	41	8	3			1	1		94
9	84	22	5	1	56	13	1	2		2		1	103
10	13	3	1	1	9	1	1		1	1			18
TOTAL	285	88	61	19	145	25	8	6	1	4	7	1	365
No Soil Left for pH	14	4	4	5	5	2	1						

The evergreen xerophytic nature of the Western Australian vegetation combined with large areas of low rainfall are not conducive to supplying large quantities of organic matter for the soil.

Of all the soil samples examined only a few of the garden soils from the Perth metropolitan area were obviously rich in organic matter. Particularly noted were garden soils from Kalamunda, South Perth and one Guildford sample.

If any fungus was observed to be more frequently associated with the presence of organic matter it was *M. cookei*. *M. gypseum* was present in many soils which appeared to be devoid of organic matter. The various *Chrysosporium* species were recovered from most soils in W.A. and do not seem to be dependent on the presence of organic matter. *C. evolceanui* may have an association with the presence of animal manure as 3 of the isolates were from a pig farm. However, there were too few isolates of this fungus to draw any conclusions.

d) Effect of Temperature

Otcenasek *et al.* (20) deduced from data available at that time, that the geographic distribution of geophilic dermatophytes is probably in the first place determined by the influence of temperature. Dawson *et al.* (9) in laboratory experiments showed *M. gypseum* (*Nannizzia incurvata*), was better able to withstand prolonged temperatures of 37°C than *T. ajelloi* (*Arthroderma uncinatum*). The widespread occurrence in Western Australian soils of *M. gypseum* and the occurrence of *T. ajelloi* being limited to the south west corner of the state supports this information.

However, the summer soil temperate in Western Australia in unshaded areas must reach very high maximums during the daytime, and 60°C + temperatures, would be frequent even in the cooler south west of the state. These day time temperatures continue for at least four months of the year and drop to considerably lower temperatures at night time.

All of the soil samples in this survey were collected during the winter months of the year when soil temperatures would be considerably below their peak.

Comment

Considering that most of Western Australia has sandy surface soil, arid conditions with low rainfall and soil moisture, poorly vegetated areas lacking soil organic matter and very high surface soil temperatures; the number of soils which lack keratinophilic fungi were few.

It is not possible from the data available at present to draw definite conclusions as to what conditions favour or limit the presence of keratinophilic fungi in soil. It seems that conditions that are favourable in one part of the world are not necessarily so in another. What determines the dominant species is probably a complex of factors. It is logical to expect recovery of a greater variety of these fungi from garden soils and from areas frequented by humans or animals, because one would expect more keratin containing materials to be present in these soils. But it is probable that some keratinophilic fungi are present in all soils and simply more active in soils containing keratin and moisture to aid their growth. Certainly in Western Australian soils there was a wide distribution of these fungi, and it is likely that additional species will be isolated when sample techniques are varied.

Alteras and Evolceanu (4) comment that sand is usually poor in keratinophilic fungi and they found *M. gypseum* in soils rich in organic content. Many of our W.A. surface soils are sandy and poor in organic matter yet *M. gypseum* is prevalent in all areas and keratinophilic fungi generally widespread in occurrence.

Some reports emphasize the importance of pH in limiting the occurrence of these fungi. Dawson *et al.* (9) found that fungi tolerate wide pH ranges and all species grew well from pH 5 to 8 in their experiments. Marples (17) found few isolates of *T. ajelloi* in soil above pH 6, whereas in W.A. the occurrence of this fungus seems to be more related to area than to the pH of the soil (see figure 2 and tables 4 and 5). Chmel *et al.* (8) found that increased humidity is associated with an increased number of isolations of *T. ajelloi*, and there were some indications of this in W.A.

The distribution of keratinophilic fungi in Western Australia is shown in figure 2 and for the Perth metropolitan area in figure 3. When the distribution is considered with the climatic map (figure 1), and with other local environmental factors such as soil, it becomes evident that both *M. gypseum* and *C. indicum* are very tolerant species able to live under a great range of temperatures, moisture and soil conditions.

Keratinophilic fungi were recovered from most areas but there were some differences in the species isolated from different districts. In most cases it was difficult to relate these differences to any one particular factor in the habitat. There was a clear localisation indicated in W.A. for *M. cookei* and *T. ajelloi* (see figure 2), until

soils collected from Newman in the latter part of this survey grew both of these species. No environmental explanation can be found for this but one might speculate that the continual movement of people, with their pets, trucks and machinery from the south to these mining towns in the north affords a transfer of some fungal elements. It will be interesting to see if these fungi survive in the hot desert soils after the mining boom activity eases.

Western Australian surface soils are mainly sands of various colours and compositions and they usually contain only small amounts of organic matter. The south west corner of Western Australia has been inhabited by caucasians for 150 years. Previous to 1829 this state was inhabited by nomadic aboriginals. The greater part of W.A. is still only sparsely populated as it is too arid to support a large population (see figure 1). Some towns shown on this map i.e. Newman and Dampier are mining towns that have only become populated in the last decade; Warburton is an aboriginal settlement. This pattern of population may have influenced the species distribution shown in figure 2.

Most areas sampled in this survey have a population of both humans and domestic animals and some have a small wild animal population as well. To obtain an unbiased distribution pattern of keratinophilic fungi in W.A. it will be necessary to sample more localities at different times of the year. If only garden soil in the Perth metropolitan area were sampled it would give the impression that *M. cookei* was more prevalent in Western Australia than is actually the case. Al-Doory (3) in Kenya obtained fewer keratinophilic fungi in February when there was a low rainfall than in November. Most samples from W.A. were collected in winter but depending on the area this was not necessarily the wet season.

In this survey in W.A. there were interesting similarities with the findings of Garg (14), in India, who found a prevalence of *C. indicum* (34.5 %) and *M. gypseum* (11.3 %). *C. indicum* occurred mainly on the plains and *T. ajelloi* exclusively in the highlands. At Rajasthan which has a dry climate, high temperatures, loose sandy soil and thin scruby vegetation, he recovered 3 species, *C. indicum*, *C. tropicum* and *M. gypseum*. This would correspond to large areas of W.A. which have high temperatures and poor vegetation. Kashmir with its high altitude, cool climate, compact soil and rich vegetation had 10 different species, predominant being *M. gypseum* and *T. ajelloi*. Probably the habitat similarities of India and Western Australia lie in the temperature, degree of moisture and the presence or absence of good vegetation, as there are no mountainous areas in W.A. and soil types appear to be different.

There were no isolates of *T. mentagrophytes* recovered from W.A. soils although it is present in our domestic and wild animals. McGinnis and Hilger (18), from experimental evidence conclude that *T. mentagrophytes* lacks the ability to compete as a saprophyte in natural soil. It seems probable that its occasional presence in soils is of a transitory nature having recently been dropped from an animal host and that is not a soil saprophyte.

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