

# Coprophilous Mycobiota of Oman

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**Abstract**—The mycobiota of coprophilous fungi of the Sultanate of Oman was surveyed. Its distribution among the different sites and dung types was investigated. Forty five species belonging to 25 genera are reported. The genera belong to the Discomycetes, Loculoascomycetes, Pyrenomycetes, Plectomycetes, Zygomycetes, Basidiomycetes and Myxomycetes. Most of the genera and species are new records for Oman. Twenty-one species are new records for the Arabian Peninsula and four are new records for Asia. Some dung types are new substrates. The most common species were *Iodophanus carneus* and *Sporormiella minima*. More than 50% of the species were found in Al-Batinah and Salalah regions. Percentages of fungal species found on dung of camels, goats and cows were 58%, 53%, and 36% respectively.

**Key Words**—camels, cattle, goats, coprophilous fungi, survey

## Introduction

The Sultanate of Oman lies on the eastern side of the Arabian Peninsula semi-desert within the boundaries of 16° 40'N – 26° 20'N latitude and 51° 50' E – 79° 40' E longitude (Fig. 1). Rainfall is rare with an erratic pattern, typical of desert and semi-desert climates. There are no comprehensive detailed studies of the flora of Oman but regional checklists exist (Mandaville 1977; Miller & Morris 1988; Ghazanfar 1991, 1992; Miller & Cope 1996). The most important feature of the flora is its close relationship with the East African and Southwest Asian floras (Ghazanfar 1992).

The livestock population of Oman consists of cattle, sheep, camels, goats and donkeys. Camels and goats predominate and are dispersed throughout Oman. The majority of the livestock obtain their feed partly from grazing and partly from hand feeding of commercial pelleted food due to uncertain rainfall and ,hence, unavailability of the forage.

Little is known about the coprophilous fungi of the Arabian Peninsula (Ahmed et al. 1971a,b; Abdullah et al. 1976, 1978; Abdullah 1982; Bokhary 1985, 1986 , 1987; Bokhary & Parvez 1986; Bokhary et al. 1989; Taj Al-Deen et al. 1990). No study has been carried out on the coprophilous fungi of Oman.

The objective of this study is to obtain information on the mycobiota of coprophilous fungi associated with different dung types in an arid environment and to compare their distribution among different sites and dung types in Oman.

## Materials and Methods

One hundred and ten dung samples were collected from the different sites in the Sultanate of Oman (Fig. 1). Three samples each of camel, goat and donkey dung were collected from each site. Three samples of cattle dung were collected from all sites except Yalooni and Wahiba Sands. Eight samples each of oryx, ibex and gazelle were collected from one site (Yalooni). Eight samples of tahr dung were collected from one site (Al Zahra). The samples collected, ranged between fresh to semi fresh, were stored at room temperature ( $24 \pm 2^{\circ}\text{C}$ ) and were examined within three weeks of collection. Each sample was soaked in distilled water for a few minutes and placed in a sterile crystalline dish containing sterilized moistened absorbent cotton lined with wet filter papers. The dishes were covered with small glass plates, incubated at room temperature  $24 \pm 2^{\circ}\text{C}$  and placed near a window. The samples were examined every four days for up to three months. Fungi that subsequently developed on the dung were examined and identified.

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**Table 1.** Incidence of occurrence and distribution of Coprophilous fungi in Oman

	Fungi	Occurrence*	Distribution <sup>s</sup>	Herbarium	
				SQU**	FMR***
	<b>Discomycetes</b>				
1	<i>Ascobolus hawaiiensis</i> Brumm.	E	BCDE	40	-
2	<i>Ascobolus immersus</i> Pers.	C	AK <sub>2</sub> Z <sub>2</sub> Z <sub>3</sub> Z <sub>4</sub> H	43	3682
3	<i>Ascobolus stictoides</i> Speg.	B	A	39	-
4	<i>Saccobolus citrinus</i> Boud. & Torrend	C	ADC	41	3700
5	<i>Saccobolus minimus</i> Velen.	B	K <sub>1</sub>	42	3698
6	<i>Saccobolus versicolor</i> (P.Karst) P.Karst	B	K <sub>2</sub>	50	3699
7	<i>Coprotus aurora</i> (P.Crouan & H.Crouan) K.S.Thind & Waraitch	B	CK <sub>1</sub> K <sub>2</sub>	3	3684
8	<i>Coprotus disculus</i> Kimbr., Luck-Allen & Cain	E	AGJK <sub>1</sub> P <sub>2</sub> TZ <sub>2</sub> Z <sub>4</sub> P <sub>1</sub> RR <sub>1</sub>	1	3685
9	<i>Coprotus dhofarensis</i> Gené, ElShafie & Guarro	A	Z <sub>4</sub>	51	3921
10	<i>Coprotus granuliformis</i> (P.Crouan & H.Crouan) Kimbr.	E	BDK <sub>1</sub> M	2	3696
11	<i>Coprotus leucopocillum</i> Kimbr., Luck-Allen & Cain	E	JK <sub>1</sub> K <sub>2</sub> P <sub>2</sub> Z <sub>5</sub> Q	4	3686
12	<i>Lasiobolus intermedius</i> J.L.Bezerra & Kimbr.	B	FG	36	-
13	<i>Lasiobolus microsporus</i> J.L.Bezerra & Kimbr.	B	FG	37	-
14	<i>Lasiobolus trichoboloides</i> S.R.Khan & J.L.Bezerra	B	FG	45	-
15	<i>Lasiobolidium orbiculoides</i> Malloch & Benny	B	V	48	3701
16	<i>Iodophanus carneus</i> (Pers.) Korf	F	IJK <sub>2</sub> K <sub>3</sub> LMNP <sub>1</sub> P <sub>2</sub> TWY	28	3703
17	<i>Iodophanus verrucosporus</i> (P.W.Graff) Kimbr., Luck-Allen & Cain	B	K <sub>2</sub> Z <sub>2</sub>	44	-
18	<i>Ascodesmis nigricans</i> Tiegh.	B	DEFZ <sub>5</sub>	35	-
19	<i>Thecotheus harasisus</i> Gené, ElShafie & Guarro	A	AG	34	4159
	<b>Loculoascomycetes</b>				
20	<i>Sporormiella australis</i> (Speg.) S.I.Ahmed & Cain	B	DFZ <sub>3</sub>	31	-
21	<i>Sporormiella intermedia</i> (Auersw.) S.I.Ahmed & Cain	B	D	32	-
22	<i>Sporormiella minimoides</i> S.I.Ahmed & Cain	B	K <sub>2</sub>	33	-
23	<i>Sporormiella minima</i> (Auersw.) S.I.Ahmed & Cain	F	IJK <sub>1</sub> K <sub>2</sub> P <sub>2</sub> UWXYZ <sub>1</sub> S	30	-
24	<i>Delitschia marchalii</i> Berl. & Voglino	A	A	25	-
25	<i>Faurelina indica</i> Arx, Mukerji & N. Singh	B	A	10	3691
	<b>Pyrenomyces</b>				
26	<i>Arnium arizonense</i> (Griffiths) N.Lundq. & J.C.Krug	B	K <sub>2</sub> Z <sub>4</sub>	21	-
27	<i>Chaetomidium khodense</i> Cano, Guarro & ElShafie	A	A	14	3688
28	<i>Chaetomium bostrychodes</i> Zopf	B	IK <sub>2</sub> P <sub>2</sub> P <sub>3</sub>	40	3692
29	<i>Chaetomium globosum</i> Kunze	E	IJK <sub>1</sub> K <sub>2</sub> NP <sub>2</sub> U	52	-
30	<i>Chaetomium murorum</i> Corda	B	K <sub>1</sub> L	15	3689
31	<i>Lophotrichus ampullus</i> R.K.Benj.	B	K <sub>1</sub> K <sub>2</sub> J	19	-
32	<i>Lophotrichus</i> sp. 1	B	V	53	3695
33	<i>Lophotrichus</i> sp. 2	B	J	54	-
34	<i>Podospora anserina</i> (Ces. ex Rabh.) G.Winter	B	A	24	-
35	<i>Podospora prethopodalis</i> Cain	B	A	22	-
36	<i>Podospora setosa</i> (G.Winter) Niessl	D	AIJK <sub>2</sub> Y	62	-
37	<i>Sordaria fimicola</i> (Roberge ex Desm.) Ces. & De Not.	A	A	29	-
38	<i>Kernia nitida</i> (Sacc.) Nieuwl.	B	BZ <sub>5</sub>	6	-
39	<i>Zopfiella erostrata</i> (Griffiths) Udagawa & Furuya	B	BDFV	5	3690
40	<i>Cercophora</i> sp.	B	A	23	3702
	<b>Plectomyces</b>				
41	<i>Gymnoascus dankaliensis</i> (Castell.) Arx	B	K <sub>2</sub>	18	-
42	<i>Neosartorya fischeri</i> (Wehmer) Malloch & Cain	B	AK <sub>2</sub>	17	3694
	<b>Myxomycetes</b>				
43	<i>Physarum</i> sp.	B	K <sub>1</sub> K <sub>2</sub> MUU <sub>1</sub> Z <sub>3</sub> Z <sub>4</sub>	55	-
	<b>Basidiomycetes</b>				
44	<i>Coprinus</i> sp.	C	UZ <sub>3</sub> Z <sub>4</sub>	57	-
	<b>Zygomycetes</b>				
45	<i>Pilobolus kleinii</i> Tiegh.	B	TZ <sub>2</sub> Z <sub>4</sub>	56	-

\*Occurrence — **A** = extremely rare (found in <2%); **B** = very rare (found in 2-5%); **C** = rare (found in 6-10%); **D** = common (found in 11-20%); **E** = very common (found in 21-30%); **F** = extremely common (found in ≥ 31%)

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<sup>s</sup>See map for distribution

## Results

Table 1 shows a list of fungi, their incidence of occurrence, distribution and herbarium numbers. The table shows a total of 45 species belonging to 25 genera. All the genera and species except *Coprotus dhofarensis*, *Thecotheus harasisus* and *Chaetomidium khodense* (Gene et al. 1993 and Cano et al. 1993) are new records for Oman. The genera are distributed taxonomically as follows: Discomycetes (8 genera, 19 species; 42.2% of the species); Loculoascomycetes (3 genera, 6 species; 13.3% of the species); Pyrenomycetes (9 genera, 15 species; 33.3% of the species); Plectomycetes (2 genera, 2 species; 4.4% of the species); Myxomycetes, Basidiomycetes, and Zygomycetes (one genus, one species; 2.2% each of the species). Species of Discomycetes and Pyrenomycetes are the most common (75.5%). Five species were recorded for *Coprotus*, 4 for *Sporormiella*, 3 for *Ascobolus*, *Saccobolus*, *Lasiobolus*, *Chaetomium*, *Lophotrichus*, and *Podospora*; 2 for *Iodophanus* and one for each of the remaining genera.

Most of the fungal species were very uncommon and were found in less than 5% of dung examined (Table 1). The species that were extremely common ( $\geq 31\%$ ) were *Sporormiella minima* and *Iodophanus carneus*. Other common fungal species found in 21-30% of the samples were *Ascobolus hawaiiensis*, *Coprotus disculus*, *Coprotus granuliformis*, *Coprotus leucopocillum* and *Chaetomium globosum*.

### Distribution of the fungal species among the sites

Tables 1, 2 and Fig. 1 show the distribution of the fungal species among the sites. More than half of the species were found in Al-Batinah (26 species; 58%) and Salalah (24 species; 53%) regions. These two areas are the main agricultural areas of country and are irrigated.

About one quarter of the species were found in Al-Dakhliya (12 species, 27%) and Al-Sharqia and Yalooni (11 species, 24%). About 18% and 13% of the species were found in the desert areas of Al-Zahra and Wahiba sands respectively.

Some fungi were found only in one site while others were distributed in all sites. These, which were found only in the Al-Batinah were *Saccobolus minimus*, *Saccobolus versicolor*, *Sporormiella minimoides* and *Gymnoascus damkaliensis* while those which were found only in Salalah were *Ascobolus stictoideus*, *Coprotus dhofarensis*, *Delitschia marshalii*, *Chaetomidium khodense*, *Faurelina indica*, *Podospora anserina*, *Podospora prethopodalis*, *Sordaria fimicola*, *Cercophora* sp. and *Pilobolus kleinii*. *Iodophanus carneus*, which is extremely common, was found in all of the 7 sites while *Sporormiella minima* was found in 6 sites. The rest of the species were found in 2 to 5 sites. Some were found only in Al-Batinah and Salalah; these were *Ascobolus immersus*, *Arniium arizonense*, *Neosartorya fisheri* and *Coprinus* sp.

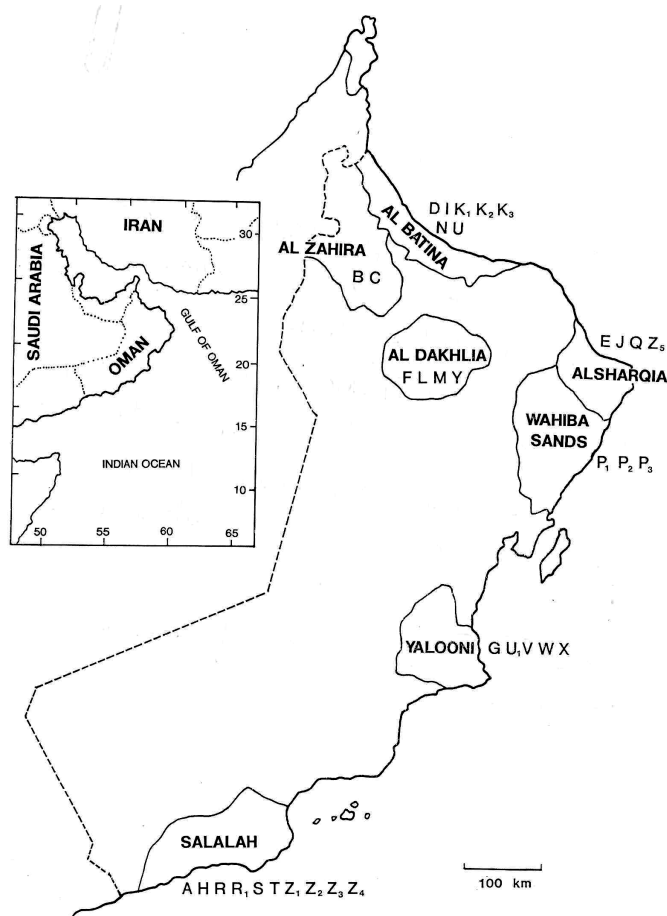
### Distribution of coprophilous fungi among the dung of animals

**Table 3** shows the distribution of the fungal species among the dung types of animals. Twenty seven species (17 genera) were found on camel dung; 24 species (15 genera) were found on goat dung; 16 species (14 genera) were on cattle dung and 1-7 species on the dung of other animals such as oryx, donkey, gazelle, ibex and tahr. Species of Discomycetes (19 species) were the most common species found in this study. Of these 19 species, 5 were found on cattle dung, 10 on camel dung, 12 on goat dung, and 6 on oryx dung. The most common group were species belonging to Pyrenomycetes (15 species). Of these 7 species were found on cattle dung, 9 on camel dung and 5 on goat dung.

Some fungi were found only on one dung type. Of the 16 fungal species found on cattle dung, 7 were restricted to cow dung and were not found on other dung types. Three species out of 24 species, and 7 species out of 27 species were restricted to goat and camel dung respectively (Table 3).

Some fungi were found on more than one dung type. Thirteen species out of the total 45 species were found on both camel and goat dung, 6 on camel and cattle dung, 5 on cattle and goat dung and 3 on dung of cattle, goats and camels.

Some species are new to the Arabian Peninsula and/or to Asia. Some dung types are new substrates (Table 3).



## Discussion

Eight genera of Discomycetes (Table 1) were found on different dung types in this study. The same genera were reported, among 11 genera, in East Africa (Khan & Krug 1994). Some of these genera are cosmopolitan and were also found in temperate and tropical habitats.

Thirty nine genera of Pyrenomycetes and nine genera of Loculoascomycetes were reported in East Africa (Khan & Krug 1994). In our survey we found only 9 genera of Pyrenomycetes, two of which, namely *Chaetomidium* and *Zopfiella*, were not reported in East Africa. Of the nine Loculoascomycetes recorded in East Africa (Khan & Krug, 1994) three genera namely *Delitschia*, *Sporormiella* and *Faurelina* were also found in Oman.

Our study has shown that 75.5% of our species were Discomycetes and Pyrenomycetes. Similar results were reported by Khan & Krug (1989, 1994). If we compare the number of species in some of our genera with the number of species of similar genera in East Africa we find *Coprotus* (4 vs. 9), *Sporormiella* (4 vs. 28), *Ascobolus* (3 vs. 7), *Saccobolus* (3 vs. 9), *Lasiobolus* (3 vs. 6) and *Chaetomium* (3 vs. 32). The number of the species is fewer in our study than for East Africa. This difference in number of species between Oman and East Africa could be due to the difference in the number of samples studied. Richardson (2001) found that there was an increase in the number of species recorded with an increase in the number of samples.

**Table 2.** Distribution of fungal species among the sites.

Fungal species	Al Batina	Al Zahra	Al Dakhliia	Al Sharqia	Wahiba Sands	Yaloni	Salalah
1	+	+		+			
2	+						+
3							+
4	+	+					+
5	+						
6	+						
7	+	+					
8	+			+	+	+	+
9							+
10	+	+	+				
11	+			+	+		
12			+			+	
13			+			+	
14			+			+	
15						+	
16	+	+	+	+	+	+	+
17	+						+
18	+		+	+			
19						+	+
20	+		+				+
21		+					
22	+						
23	+		+	+	+	+	+
24							+
25							+
26	+						+
27							+
28	+				+		
29	+			+	+		
30	+		+				
31	+			+			
32						+	
33			+	+			+
34							+
35							+
36	+		+	+		+	+
37							
38				+			
39	+	+					+
40		+					
41	+						+
42	+						+
43	+		+			+	+
44	+						+
45							
% occurrence →	58%	18%	27%	24%	13%	24%	51%

**Table 3.** Distribution of fungal species among the dung of animals.

Fungal species	New records	Frequency of occurrence*	Cattle	Camel	Goat	Oryx	Donkey	Gazelle	Ibex	Tahr
1	••	E		++	++					
2		C		+	+					
3	•	B	+							
4	•	C	+		+					
5		B		++						
6	•	B		++						
7	•	B		++	+					
8	••	E	+	++	++	++	++			
9		A			+					
10	•	E		++	+					
11	•	E		++			+			+
12	•	B			++	++				
13	•	B			+	+				
14	•	B			++	++				
15		B			+	+				
16		F		+	+			+		
17	•	B	++	++	+					
18	•	B								++
19		A	+		+	+				
20		B		+	+					
21		B								
22	•	B		+	+					
23		F	+	+				+	++	
24	•	A	+		+					
25	•	B		+	+					
26	•	A	+	++	+					
27		B		+	+					
28		E		+	+					
29		B								
30		B	+	++						
31		B								
32		B		+		+				
33	•	B								
34		B	+							
35		B	+	++	+					
36		D	+							
37		A	+							
38	•	B		+	+					++
39		B								
40		B	+							
41		B		++						
42		B	+	++						
43	•	B		+	+					
44	••	C			+					
45		B	+				+			
% occurrence—>		36%	58%	53%	16%	4%	4%	2%		

\*Frequency— **A = extremely uncommon** (found in <2% of the dung examined); **B = very rare** (found in 2-5% of the dung examined); **C = rare** (found in 6-10% of the dung examined); **D = common** (found in 11-20% of the dung examined); **E = very common** (found in 21-30% of the dung examined); **F = extremely common** (found in ≥ 31% of the dung examined)  
• = new to Arabian Peninsula; •• = new to Asia; ++ = new dung substrate

The most abundant fungi we found in our study were *Sporormiella minima*, *Iodophanus carneus*, *Coprotus disculus*, *C. granuliformis*, *C. leucopocillum* and *Chaetomium globosum*. The majority of these species are common and have been reported in East Africa. (Khan & Cain 1972, 1979; Caretta et al. 1998; Carter & Khan 1982).

Table 2 shows the distribution of fungal species among the sites with more abundant species in Al-Batinah and Salalah than the other areas. These sites are the main agricultural areas of Oman and hence show more diversity and abundance of animals and plants. Wahiba Sand, Al-Zahra and Yalooni are extensions of the Arabian Peninsula desert where there are few animals (camels, goats and donkeys) and little vegetation and hence fewer fungi.

Some fungi in this study were found only on one dung type. The fungal species composition has been shown to be dependent upon the type of stomachs, digestive processes, feeding habits and food preferences of the animals (Webster 1970; Parker 1979; Wicklow & Moore 1974; Wicklow et al. 1980; Angel & Wicklow 1975, 1983; Piontelli et al. 1981; Ebersohn & Eicker 1992; Caretta et al. 1994).

In this study, we did not attempt to make quantitative assessment of the diversity and species richness. Our aim was to survey the coprophilous mycobiota of an "extreme" environment that has not been studied before and to compare it with the nearest well studied area such as East Africa. The diversity, richness and occurrence of coprophilous fungi on different dung types from different places, latitudinal ranges and seasons were well studied and documented (Cain 1934; Furuya & Udagawa 1972a, b; Lundqvist 1972; Angel & Wicklow 1975, 1983; Parker 1979; Udagawa & Muroi 1979; Udagawa 1980; Wicklow 1981, 1992; Bell 1983; Caretta et al. 1994; Richardson 2001).

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