Biodiversity of mangrove fungi on different substrata of *Rhizophora apiculata* and *Avicennia* spp. from Godavari and Krishna deltas, east coast of India

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Sarma, V.V. and Vittal, B.P.R. (2000). Biodiversity of mangrove fungi on different substrata of *Rhizophora apiculata* and *Avicennia* spp. from Godavari and Krishna deltas, east coast of India. In: *Aquatic Mycology across the Millennium* (eds K.D. Hyde, W.H. Ho and S.B. Pointing). Fungal Diversity 5: 23-41.

The fungal diversity on prop roots, seedlings and wood of *Rhizophora apiculata* and wood, roots and pneumatophores of *Avicennia* spp. has been investigated. Decomposing substrata were collected from the deltaic mangroves of Godavari and Krishna rivers, in the east coast of India. The number of fungi recorded on prop roots of *Rhizophora apiculata* (61) was much greater when compared to wood (24) and seedlings (21). Of the 63 species recorded, twelve were common to all three substrata; ten were common to wood and prop roots, twelve to seedlings and wood and nine to prop roots and seedlings. Thirty-two species were recorded exclusively on prop roots. *Verruculina enalia* was frequently recorded on all the three substrata, but its percentage occurrence on prop roots (13.1) was lower than that on seedlings (23.8) and wood (23.4). *Dactylospora haliotrepha* was very frequent on wood, frequent on prop roots and rare on seedlings. *Lophiostoma mangrovei* was frequent on wood and seedlings and rare on prop roots. *Saccardoella rhizophorae* and *Phomopsis mangrovei* were very frequent on seedlings and absent on wood. The number of fungal species recorded on *Avicennia* wood (61) was much greater when compared to pneumatophores (14) and roots (17). Seven species were common to all the three substrata; four to wood and pneumatophores; eight to wood and roots and one to pneumatophores and roots. Forty-two fungi were recorded only on wood. *Verruculina enalia* was very frequent on all three substrata but its percentage occurrence on wood (24.7) was slightly higher when compared to roots (22.9) and pneumatophores (18.9). *Lulworthia* sp. was very frequently recorded on pneumatophores and roots but was infrequent on wood. *Leptosphaeria australiensis* was very frequent on pneumatophores, was frequent on roots, and rare on wood. Such differences in percentage occurrence also appeared with respect to other fungi common to all the three substrata of the respective hosts.

Key words: mangicolous fungi, pneumatophores, prop roots, roots, seedlings, substratum preference, wood.

Introduction

Mangroves are tropical and subtropical forests comprising trees of many unrelated genera that share the common ability to grow in estuarine and coastal environments. They are open systems with respect to both energy and matter and thus couple upland terrestrial and coastal estuarine ecosystems (Lugo and Snedaker, 1974). Mangrove vegetation contributes to the primary production in the aquatic environment in the form of leaf and litter fall. Decomposition of this organic material by bacteria and fungi results in protein enriched fragments of detritus. Fungi rather than bacteria have been considered to be principal sources of this increase in nitrogen (Odum and Heald, 1972). Despite a better understanding of the importance of mangroves, they continue to be destroyed at an alarming rate (Ong, 1995). Therefore it is imperative to record and quantify the abundance of marine fungi in the mangrove ecosystem and to culture them to ensure their conservation for future biochemical, genetic and molecular studies (Jones and Mitchell, 1996).

Although mangroves are the second important habitats for marine fungi after driftwood, reports on marine fungi on mangroves were not published until Cribb and Cribb (1955) reported their collections of fungi on mangrove roots in Australia. Investigations on marine mangrove fungi have however, received considerable attention. The mycota of several of the tropical and subtropical mangrove substrata has been documented. Apart from isolating several interesting fungi, information was also gathered on the biogeography and ecology of these fungi (see Hyde and Lee, 1995; Jones and Alias, 1997).

Mangroves are dominant along Indian coastline and provide niches and habitats for many marine and estuarine organisms. However, very few attempts have been made to investigate the fungi associated with decaying substrata of mangrove plants. This is especially true with mangroves of the east coast of India, which accounts for approximately 33% of the total Indian mangroves (Untawale, 1987). The total area covered by mangroves in India is estimated to be about 6,700 sq km. which constitutes about 7% of the world mangroves. The extent of mangroves along the east coast is larger than the west coast. Along the Indian coast, major deltas are confined to east coast and harbor some of the best mangrove swamps in the world, located in the alluvial deltas of rivers such as Cauvery, Ganges, Godavari, Mahanadi and Krishna. Almost 70% of the total mangrove cover of India exists in the deltaic regions (Untawale and Jagtap, 1992).

The first marine fungus from Indian mangroves was reported from east coast by Raghu Kumar (1973). There have however been no efforts to study the marine fungi on mangroves until recently when systematic studies on manglicolous fungi in India were initiated. A detailed investigation of fungi on

mangroves of west coast was made by Patil and Borse (1983, 1985a,b), Borse (1988a,b), Borse and Hyde (1989), Chinnaraj and Untawale (1992), Chinnaraj (1993a,b). However vast tracts of mangroves on the east coast remained virtually unexplored except for the studies of Ravikumar (1991) and Ravikumar and Vittal (1996).

A survey of the intertidal fungi on mangroves at Godavari and Krishna deltas, Andhra Pradesh state (east coast of India), which have not been previously investigated was therefore initiated. The paper addresses fungal diversity on wood, seedlings and prop roots of *Rhizophora apiculata* (*Rhizophoraceae*) and wood, roots and pneumatophores of *Avicennia marina* and *A. officinalis* (*Avicenniaceae*).

Materials and methods

Godavari Delta

The mangroves of Godavari delta cover about 13,304 ha (Sidhu, 1963) and the area falls within a latitude of 16°14' and 16°45'N and longitude of 82°14' and 82°20'E. Samples were collected from Coringa and Balusutippa mangroves situated at Yanam, near Kakinada town (Fig. 1).

Krishna Delta

The mangroves of Krishna delta cover about 5,120 ha (Sidhu, 1963) and the area falls within a latitude of 15°50' and 15°55'N and longitude of 80°45' and 80°50'E. The samples were collected from Kothapalem mangroves near Repalle (Fig. 1).

The study was carried from August 1993 to November 1995. After initial collections trips i.e. one to Godavari in August 1993 and one to Krishna in November 1993 regular collecting trips were made to both sites at bimonthly intervals. The samples collected from the respective collection sites were placed in large polythene bags for transport to the laboratory. They were examined immediately, as well as following incubating in moist chambers.

Presentation of data

The term "percentage occurrence" is used to denote the number of samples on which a particular fungus was found as against the total number of samples (supporting sporulation) examined in each bimonthly collection and is calculated according to the formula outlined by Hyde (1986) and Jones and Hyde (1988):

$$\text{Percentage occurrence} = \frac{\text{Number of samples on which a particular fungus is recorded}}{\text{Total number of samples examined supporting sporulating fungi}} \times 100\%$$

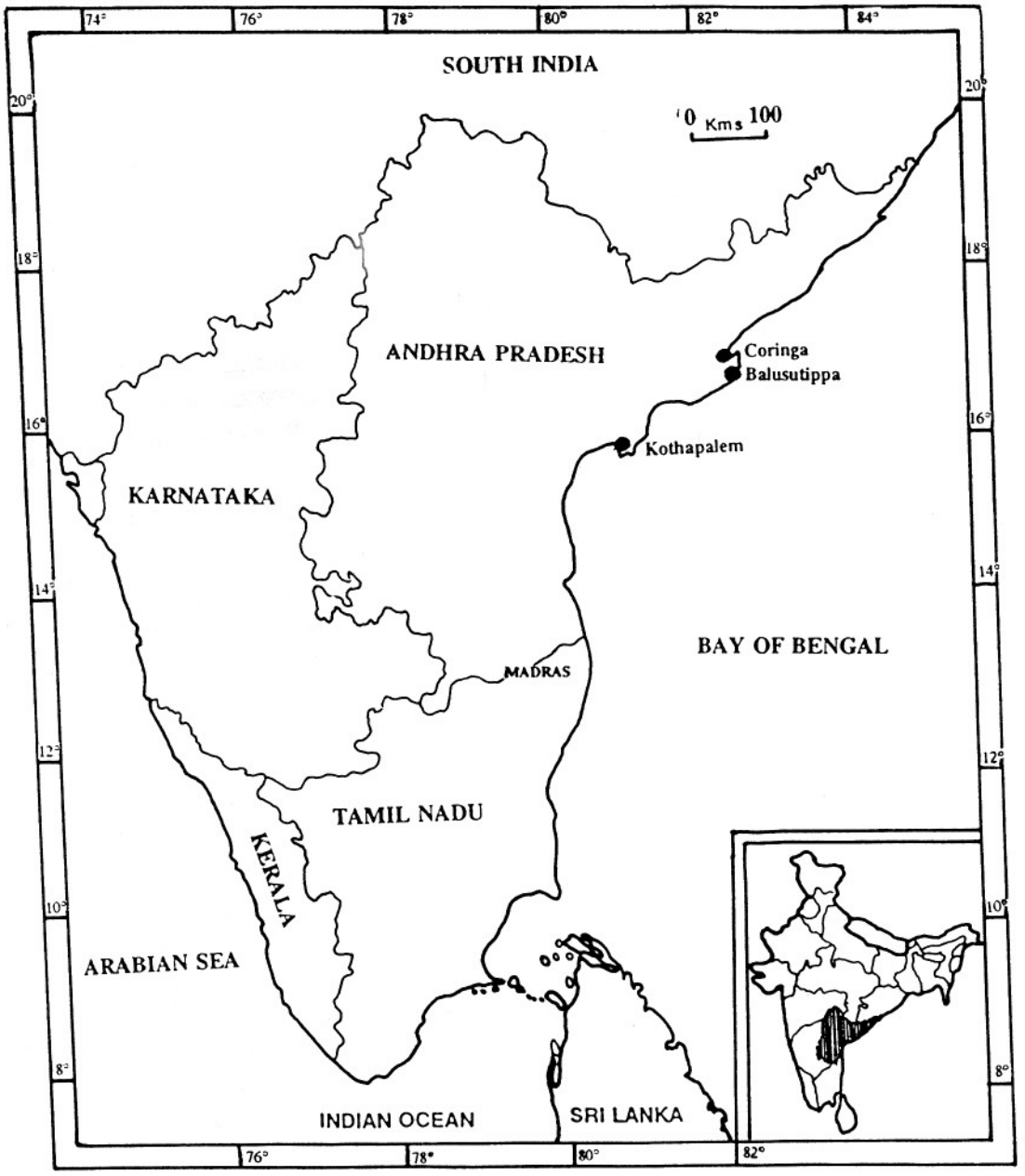

Fig. 1. Map of South India showing collection sites.

On the basis of percentage occurrence, the following frequency groupings were made:

1. Very Frequent : occurring in more than 10% of samples
2. Frequent : above 5% and below 10%
3. Infrequent : above 1% and below 5%
4. Rare : below 1%

Results

Fungi colonizing different substrata of Rhizophora apiculata

Twenty-one species including 13 ascomycetes, 1 basidiomycete and 7 mitosporic fungi were recorded from 273 seedling samples examined (Table 1). *Verruculina enalia* (23.8%), *Phomopsis mangrovei* (18.3%) and *Saccardoella rhizophorae* (17.6%) were very frequent. *Lophiostoma mangrovei* was recorded frequently.

Twenty-four species belonging to 23 genera were recorded from the 192 wood samples of *Rhizophora apiculata* examined. These included 17 ascomycetes, 1 basidiomycete and 6 mitosporic fungi (Table 1). *Verruculina enalia* (23.4%), *Dactylospora haliotrepha* (12.5%) and *Hysterium* sp. (10.4%) were very frequent on wood. Among the three fungi that were frequent, *Lophiostoma mangrovei* (9.4%) was more frequent than *Epicoccum purpurascens* (6.8%) and *Trichocladium achrasporum* (5.2%).

Sixty-one species belonging to 45 genera were identified from 2524 samples of prop roots examined. These included 42 ascomycetes, 1 basidiomycete and 18 mitosporic fungi (Table 1). *Verruculina enalia* (13.1%) was very frequent followed by *Rhizophila marina* (11.7%). *Cirrenalia pygmae* (8.7%), *Cryptosphaeria mangrovei* (6.2%) and *Dactylospora haliotrepha* (5.5%) were the frequently recorded species. Many species (37) were rare with less than 1% occurrence.

Comparison of fungal diversity on different substrata of Rhizophora apiculata

The number of fungi recorded on prop roots (61) was much greater when compared with seedlings (21 species) and wood (24 species) (Fig. 2; Table 1). Of the 63 species recorded, 12 were common to all the three substrata; 10 were common to wood and prop roots, 12 to seedlings and wood, and 9 to prop roots and seedlings.

Although many fungi were common to all three substrata their percentage occurrence differed (Fig. 3). *Verruculina enalia* showed a higher percentage occurrence on seedlings (23.8%) and wood (23.4%), than on prop roots (13.1%). *Dactylospora haliotrepha* which was very frequent on wood (12.5%), was frequent on prop roots (5.5%) and rare on seedlings (0.7%). Similarly *Lophiostoma mangrovei* which was frequent on wood (9.4%) and seedlings (8.1%) was rare on prop roots (1.5%). *Saccardoella rhizophorae* and *Phomopsis mangrovei* which were very frequent on seedlings, were absent on wood and infrequent or rare on prop roots. Such differences in percentage occurrence were observed with other fungi which were common to all the three substrata.

Fungi colonizing different substrata of Avicennia *spp.*

From the 118 root samples examined, 17 species including 12 ascomycetes, 1

Table 1. Comparison of percentage occurrence of fungi among seedlings, wood and prop roots of *Rhizophora apiculata*.

Fungi	Seedlings			Wood			Prop roots		
	No. of collections	% occurrence	FI	No. of collections	% occurrence	FI	No. of collections	% occurrence	FI
Ascomycetes									
Aigialus grandis Kohlm. and S. Schatz	0	0		4	2.1	IF	38	1.5	IF
A. parvus S. Schatz and Kohlm.	0	0		0	0		2	0.07	R
Aniptodera chesapeakensis Shearer and Miller	0	0		0	0		2	0.07	R
A. haispora Vrijmoed, K.D. Hyde and E.B.G. Jones	0	0		0	0		1	0.03	R
A. mangrovei K.D. Hyde	3	1.1	IF	0	0		21	0.8	R
Ascocratera manglicola Kohlm.	0	0		1	0.5	R	0	0	
Chaetomastia typhicola (Karsten) Barr	0	0		0	0		0	0.1	R
Corollosporella pulchella Kohlm., I. Schmidt and Nair	0	0		0	0		4	0.2	R
Cryptosphaeria mangrovei K.D. Hyde	9	3.3	IF	4	2.1	IF	156	6.2	F
Dactylospora haliotrepha (Kohlm. and E. Kohlm.) Hafellner	2	0.7	R	24	12.5	VF	140	5.5	F
Gnomonia sp.	0	0		0	0		5	0.2	R
Halorosellinia oceanica Whalley, E.B.G. Jones, K.D. Hyde and Læssøe	7	2.6	IF	6	3.1	IF	44	1.7	IF
Halosarpheia abonnis Kohlm.	0	0		0	0		83	3.3	IF
H. marina (Cribb and J.W. Cribb) Kohlm.	0	0		0	0		1	0.03	R
H. ratnagiriensis S.D. Patil and Borse	0	0		0	0		43	1.7	IF
Halosarpheia sp.	0	0		0	0		16	0.6	R
Heleococcum japonense Tubaki	0	0		0	0		9	0.4	R
Hypocrea sp.	0	0		2	1.0	IF	2	0.07	R
Hypoxylon sp.	0	0		5	2.6	IF	7	0.3	R
Hysterium sp.	0	0		20	10.4	VF	28	1.1	IF
Kallichroma tethys Kohlm. and Volkm.-Kohlm.	0	0		0	0		8	0.3	R
Kirschsteiniothelia maritima-like	0	0		0	0		1	0.03	R
Lecanidion atratum (Hedw. ex Fr.) Endl.	0	0		3	1.6	IF	8	0.3	R

FI = Frequency Index; VF = Very Frequent; F = Frequent; IF = Infrequent; R = Rar.

Table 1. (continued).

Fungi	Seedlings			Wood			Prop roots		
	No. of collections	% occurrence	FI	No. of collections	% occurrence	FI	No. of collections	% occurrence	FI
Leptosphaeria australiensis (Cribb and J.W. Cribb) G.C. Hughes	3	1.1	IF	6	3.1	IF	49	1.9	IF
Leptosphaeria peruviana Speg.	0	0		0	0		28	1.1	IF
Leptosphaeria sp.	0	0		0	0		1	0.03	R
Lignincola longirostris (Cribb and J.W. Cribb) Kohlm.	0	0		0	0		1	0.03	R
L. tropica Kohlm.	0	0		0	0		1	0.03	R
Lineolata rhizophorae (Kohlm. and Kohlm.) Kohlm. and Volkm.-Kohlm.	0	0		0	0		21	0.8	R
Lophiostoma mangrovei Kohlm. and Vittal	22	8.1	F	18	9.4	F	39	1.5	IF
Lulworthia grandispora Meyers	8	2.9	IF	0	0		29	1.1	IF
Lulworthia sp.	11	4.0	IF	4	2.1	IF	125	4.9	IF
Massarina thalassiae Kohlm. and Volkm.-Kohlm.	0	0		0	0		14	0.6	R
M. velatospora K.D. Hyde and Borse	3	1.1	IF	7	3.6	IF	12	0.5	R
Massarina sp.	3	1.1	IF	0	0		60	2.4	IF
Passeriniella obiones (A.M. Crouan and P.L. Crouan) K.D. Hyde and Mouzouras	0	0		0	0		3	0.1	R
Pedumispora rhizophorae K.D. Hyde and E.B.G. Jones	1	0.4	R	0	0		0	0.03	R
Quintaria lignatilis (Kohlm.) Kohlm. and Volkm.-Kohlm.	0	0		1	0.5	R	0	0	
Rhizophila marina K.D. Hyde and E.B.G. Jones	0	0		5	2.6	IF	296	11.7	VF
Saccardoella rhizophorae K.D. Hyde	48	17.6	VF	0	0		118	4.7	IF
Savoryella lignicola E.B.G. Jones and R.A. Eaton	0	0		0	0		14	0.6	R
Splanchnonema britzelmayriana-like	0	0		0	0		7	0.3	R
Tubeufia setosa Sivanesan and W.H. Hsieh	0	0		1	0.5	R	5	0.2	R
Verruculina enalia (Kohlm.) Kohlm. and Volkm.-Kohlm.	65	23.8	VF	45	23.4	VF	331	13.1	VF

Table 1. (continued).

Fungi	Seedlings			Wood			Prop roots		
	No. of collections	% occurrence	FI	No. of collections	% occurrence	FI	No. of collections	% occurrence	FI
Basidiomycetes									
Halocyphina villosa Kohlm. and Kohlm.	4	1.5	IF	2	1.0	IF	95	3.8	IF
Mitosporic taxa									
Alveophoma sp.	4	1.5	IF	0	0		2	0.07	R
Bactrodesmium linderii (Crane and Shearer) Palm. and Stewart	0	0		0	0		22	0.9	R
Cirrenalia basiminuta Raghuk. and Zainal	0	0		0	0		5	0.2	R
C. macrocephala (Kohlm.) Meyers and R.T. Moore	0	0		0	0		4	0.2	R
C. pygmea Kohlm.	10	3.7	IF	2	1.0	IF	220	8.7	F
C. tropicalis Kohlm.	0	0		0	0		1	0.03	R
Cytospora rhizophorae Kohlm. and Kohlm.	0	0		0	0		9	0.4	R
Ellisembia vagum (C.G. and T.F.L. Nees) Subram.	0	0		2	1.0	IF	12	0.5	R
Epicoccum purpurascens Ehrenb.:Schlecht.	0	0		13	6.8	F	67	2.7	IF
Monodictys sp.	0	0		0	0		15	0.6	R
Periconia prolifica Anast.	1	0.4	R	0	0		41	1.6	IF
Phoma sp.	8	2.9	IF	0	0		58	2.3	IF
Phomopsis mangrovei K.D. Hyde	50	18.3	VF	0	0		19	0.8	R
Phomopsis sp.	0	0		0	0		19	0.8	R
Trichocladium achrasporum (Meyers and R.T. Moore) Dixon	10	3.7	IF	10	5.2	F	62	2.5	IF
Trichocladium alopallonella (Meyers and R.T. Moore) Kohlm. and Volkm.-Kohlm.	0	0		0	0		17	0.7	R
Trimmatostroma sp.	0	0		5	2.6	IF	48	1.9	IF
Zalerion varium (Sacc. Rouss. and Bomm.) Hughes	1	0.4	R	2	1.0	IF	35	1.4	IF
No. of samples supporting sporulating fungi	273			192			2524		

Table 2. Comparison of percentage occurrence of fungi on wood, roots and pneumatophores of *Avicennia* spp.

Fungi	Roots			Pneumatophores			Wood		
	No. of collections	% occurrence	FI	No. of collections	% occurrence	FI	No. of collections	% occurrence	FI
Ascomycetes									
Aigialus grandis	1	0.8	R	0	0		0	0	
A. mangrovei Borse	0	0		0	0		8	0.5	R
A. parvus	2	1.7	IF	0	0		1	0.05	R
Aniptodera chesapeakensis	0	0		0	0		17	0.95	R
A. haispora	0	0		0	0		5	0.3	R
A. mangrovei	0	0		0	0		4	0.2	R
Anthostomella sp.	0	0		0	0		3	0.2	R
Ascocratera manglicola	0	0		0	0		1	0.05	R
Bathyascus avicenniae Kohlm.	0	0		9	8.1	F	1	0.05	R
Cryptovalsa sp.	0	0		0	0		31	1.7	IF
Dactylospora haliotrepha	6	5.1	F	0	0		36	2.0	IF
Eutypa bathurstensis K.D. Hyde and Rappaz	0	0		0	0		460	25.9	VF
Gnomonia-like sp.	0	0		0	0		11	0.6	R
Halorosellinia oceanica	7	8.5	F	0	0		44	2.5	IF
Halosarpheia abonnis	0	0		0	0		28	1.6	IF
H. marina	5	4.2	IF	0	0		4	0.2	R
H. minuta Leong	0	0		0	0		4	0.2	R
H. ratnagiriensis	0	0		0	0		14	0.8	R
H. viscosa (I. Schmidt) Kohlm. and Volkm.-Kohlm.	0	0		0	0		2	0.1	R
Halosarpheia sp.	0	0		0	0		17	0.9	R
Hapsidascus-like sp.	0	0		0	0		2	0.1	R
Heleococcum japonense	0	0		0	0		14	0.8	R
Hypoxylon sp.	0	0		0	0		14	0.8	R
Hysterium sp.	0	0		0	0		7	0.4	R

FI = frequency index; VF = very frequent; F = frequent; IF = infrequent; R = rare.

Table 2. (continued).

Fungi	Roots			Pneumatophores			Wood		
	No. of collections	% occurrence	FI	No. of collections	% occurrence	FI	No. of collections	% occurrence	FI
Julella avicenniae (Borse) K.D. Hyde	0	0		0	0		11	0.6	R
Kallichroma tethys	0	0		0	0		1	0.05	R
Lautospora gigantea K.D. Hyde and E.B.G. Jones	0	0		0	0		1	0.05	R
Lecanidion atratum (Hedw. ex Fr.) Endl.	0	0		0	0		4	0.2	R
Leptosphaeria australiensis	6	5.1	F	13	11.7	VF	10	0.6	R
L. peruviana	0	0		0	0		2	0.1	R
Leptosphaeria sp.	0	0		0	0		3	0.2	R
Lignincola laevis Höhnk	0	0		0	0		1	0.05	R
L. longirostris	1	0.8	IF	2	1.8	IF	17	0.8	R
L. tropica	0	0		0	0		5	0.3	R
Lophiostoma mangrovei	0	10.2	VF	0	0		125	7.0	F
Lulworthia grandispora	5	4.2	IF	6	5.4	F	17	0.9	R
Lulworthia sp.	13	11.0	VF	14	12.6		72	4.1	IF
Marinosphaera mangrovei K.D. Hyde	0	0		0	0		4	0.2	R
Massarina velatospora	0	0		0	0		2	0.1	R
Massarina sp.	0	0		0	0		4	0.2	R
Mycosphaerella pneumatophorae Kohlm.	0	0		3	2.7	IF	0	0	
Nais glitra Crane and Shearer	0	0		0	0		2	0.1	R
Ophiodeira monosemeia Kohlm. and Volkm.-Kohlm.	0	0		0	0		4	0.3	R
Passeriniella obiones	0	0		0	0		1	0.05	R
Saccardoella marinospora K.D. Hyde	0	0		0	0		2	0.1	R
Savoryella lignicola	0	0		5	4.5	IF	22	1.2	IF
Verruculina enalia	27	22.9	VF	21	18.9	VF	438	24.7	VF
Zopfiella latipes (Lundqvist) Malloch and Cain	0	0		8	7.2	F	3	0.2	R

Table 2. (continued).

Fungi	Roots			Pneumatophores			Wood		
	No. of collections	% occurrence	FI	No. of collections	% occurrence	FI	No. of collections	% occurrence	FI
Z. marina Furuya and Udagawa	0	0		0	0		6	0.3	R
Zopfiella sp.	0	0		0	0		9	0.5	R
Ascomycete sp. 1	0	0		1	0.9	R	0	0	
Basidiomycetes									
Halocyphina villosa	7	5.9	F	6	5.4	F	80	4.5	IF
Mitosporic taxa									
Camarosporium roumegueri Sacc.	4	3.4	IF	19	17.1	VF	0	0	
Cirrenalia tropicalis	0	0		0	0		2	0.1	R
Dictyosporium sp.	0	0		0	0		4	0.2	R
Ellisembia vagum	0	0		0	0		2	0.1	R
Epicoccum purpurascens	0	0		1	0.9	R	10	0.6	R
Monodictys sp.	0	0		0	0		14	0.8	R
Periconia prolifica	2	1.7	IF	3	2.7	IF	3	1.0	IF
Phoma sp.	4	3.4	IF	0	0		11	0.6	R
Phomopsis sp.	2	1.7	IF	0	0		18	1.0	IF
Trichocladium achrasporum	0	0		0	0		14	0.8	R
Trichocladium alopallonella	0	0		0	0		13	0.7	R
Trimmatostroma sp.	0	0		0	0		12	0.7	R
Zalerion varium	0	0		0	0		4	0.2	R
No. of fungi supporting sporulating fungi	118			111			1775		

FI = frequency index; VF = very frequent; F = frequent; IF = infrequent; R = rare.

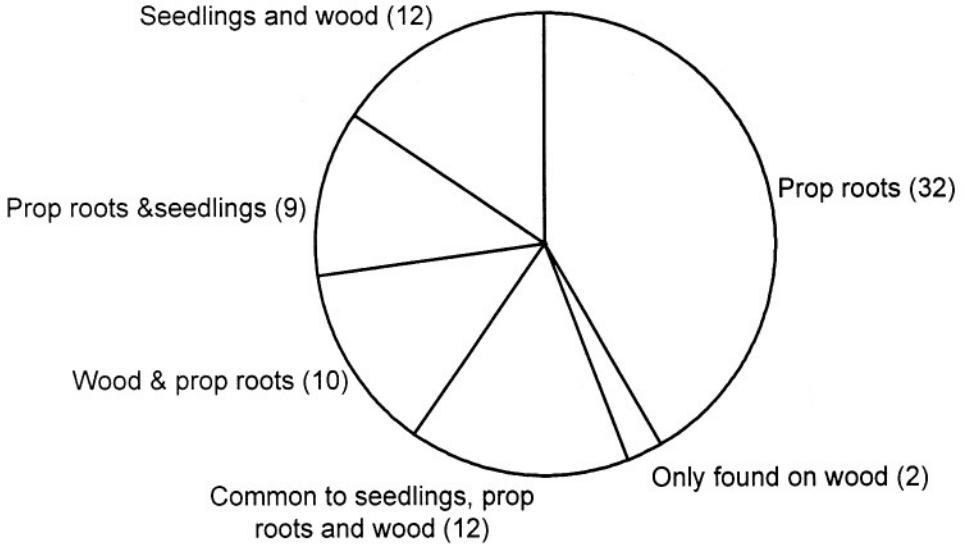

Fig. 2. Number of fungi common or restricted to different substrata of *Rhizophora apiculata.*

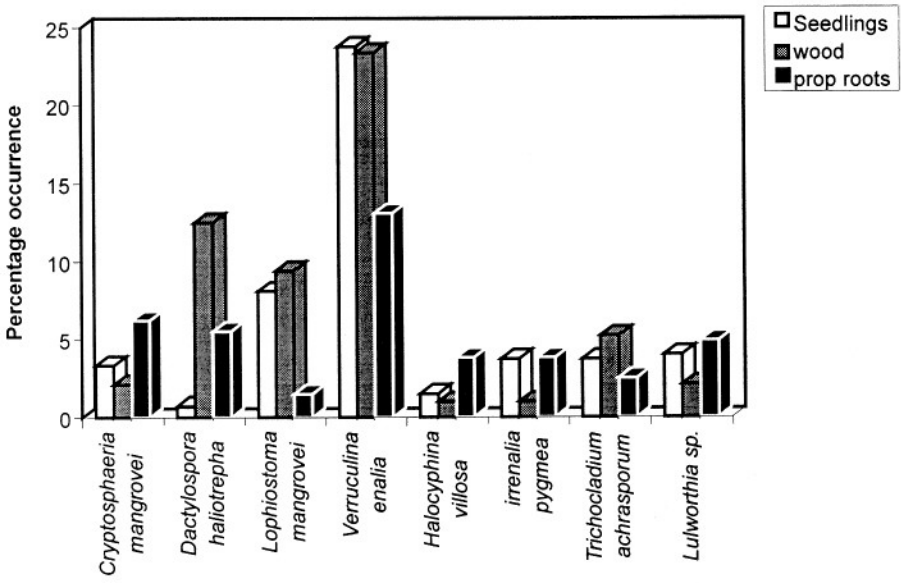

Fig. 3. Comparison of percentage occurrence of some fungi common to different substrata of *Rhizophora apiculata.*

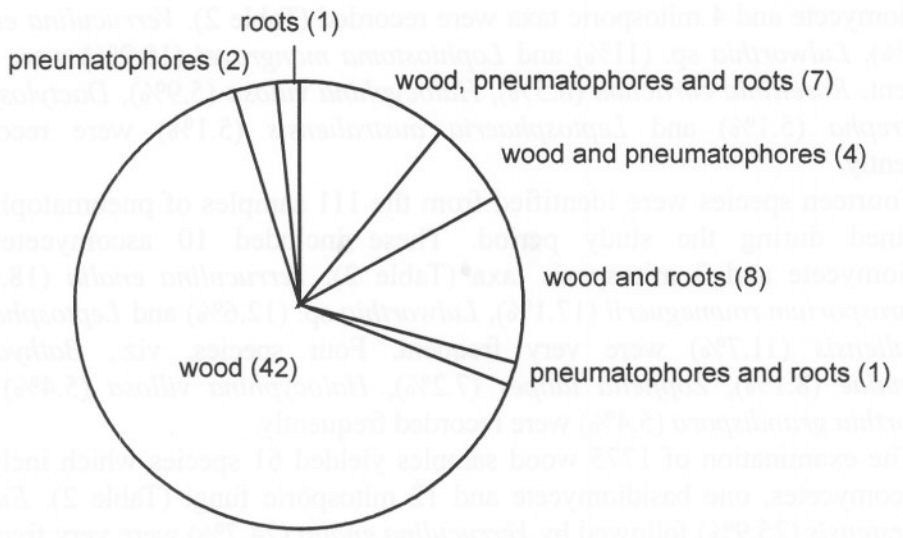

Fig. 4. Number of fungi common or restricted to different substrata of *Avicennia* spp.

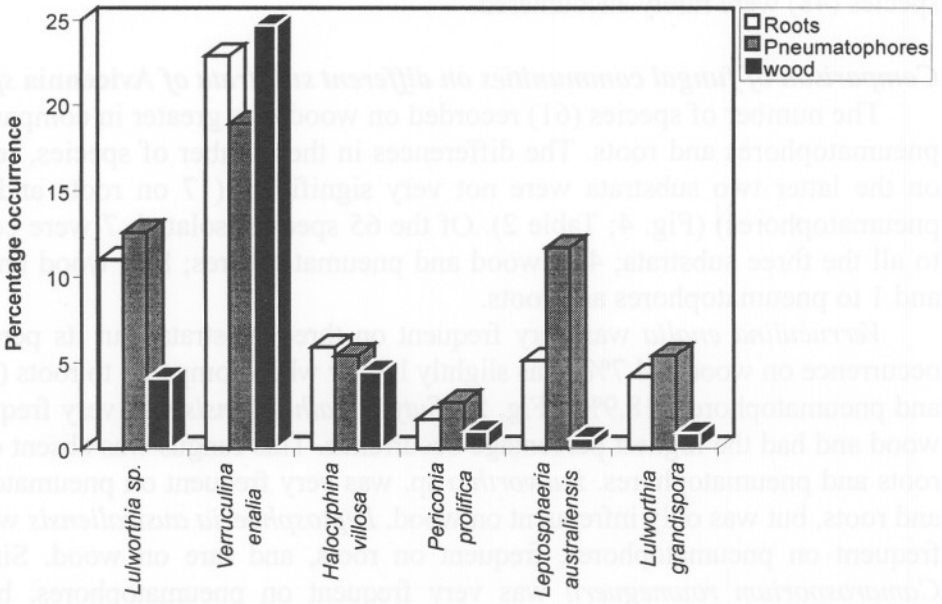

Fig. 5. Comparison of percentage occurrence of some fungi common to different substrata of *Avicennia* spp.

basidiomycete and 4 mitosporic taxa were recorded (Table 2). *Verruculina enalia* (22.9%), *Lulworthia* sp. (11%) and *Lophiostoma mangrovei* (10.2%) were very frequent. *Rosellinia corticium* (8.5%), *Halocyphina villosa* (5.9%), *Dactylospora haliotrepha* (5.1%) and *Leptosphaeria australiensis* (5.1%) were recorded frequently.

Fourteen species were identified from the 111 samples of pneumatophores examined during the study period. These included 10 ascomycetes, 1 basidiomycete and 3 mitosporic taxa (Table 2). *Verruculina enalia* (18.9%), *Camarosporium roumeguerii* (17.1%), *Lulworthia* sp. (12.6%) and *Leptosphaeria australiensis* (11.7%) were very frequent. Four species, viz., *Bathyascus avicenniae* (8.1%), *Zopfiella latipes* (7.2%), *Halocyphina villosa* (5.4%) and *Lulworthia grandispora* (5.4%) were recorded frequently.

The examination of 1775 wood samples yielded 61 species which included 48 ascomycetes, one basidiomycete and 12 mitosporic fungi (Table 2). *Eutypa bathurstensis* (25.9%) followed by *Verruculina enalia* (24.7%) were very frequent on this substratum. *Lophiostoma mangrovei* (7.0%) was the only frequently recorded species. Ten species were recorded infrequently and a large number of species (48) were rarely encountered.

Comparison of fungal communities on different substrata of* Avicennia *spp.

The number of species (61) recorded on wood was greater in comparison to pneumatophores and roots. The differences in the number of species, recorded on the latter two substrata were not very significant (17 on roots and 14 on pneumatophores) (Fig. 4; Table 2). Of the 65 species isolated, 7 were common to all the three substrata; 4 to wood and pneumatophores; 8 to wood and roots and 1 to pneumatophores and roots.

Verruculina enalia was very frequent on three substrata, but its percentage occurrence on wood (24.7%) was slightly higher when compared to roots (22.9%) and pneumatophores (18.9%) (Fig. 5). *Eutypa bathurstensis* was very frequent on wood and had the highest percentage occurrence. This fungus was absent on both roots and pneumatophores. *Lulworthia* sp. was very frequent on pneumatophores and roots, but was only infrequent on wood. *Leptosphaeria australiensis* was very frequent on pneumatophores, frequent on roots, and rare on wood. Similarly, *Camarosporium roumeguerii* was very frequent on pneumatophores, but was infrequent on roots and rare on wood. Such differences in percentage occurrence were recorded in other fungi that were common to all the 3 substrata.

Discussion

Host specificity in mangrove fungi has been reported by some workers. Hyde and Jones (1988) recognized three ecological niches within mangrove

stands: intermittently submerged wood; exposed wood of damaged mangrove roots and branches; and bark of mangrove roots and branches and noted that different fungi developed within these three niches. Kohlmeyer and Kohlmeyer (1979) reported that three fungi were found exclusively on the surface of bark of mangrove roots and branches (*Keissleriella blepharospora*, *Mycosphaerella pneumatophorae*, *Rhabdospora avicenniae*). Aleem (1980) found that the mitosporic taxa *Cirrenalia tropicalis*, *C. pygmea*, *C. macrocephala*, *Monodictys pelagica* and *Zalerion* spp. were abundant on decaying mangrove wood. In most of the above studies fungal diversity and preferential colonization on different parts of a plant: seedlings, prop roots, pneumatophores, roots and wood were not taken into consideration for comparative studies.

Fungal communities on different parts of a host plant vary and as individual substrata they influence the fungi present. Separate records were maintained in this study for the fungi identified from different substrata examined (*Avicennia* spp.: wood, pneumatophores and roots; *Rhizophora apiculata*: wood, prop roots and seedlings). Prop roots of *R. apiculata* yielded a higher number of fungi than the other two substrata (wood and seedlings). While only 2 species were recorded exclusively from wood, 32 were recorded from prop roots of *R. apiculata*. In the case of *Avicennia* spp., the maximum number of fungi (42) were found on wood, 2 on pneumatophores and 1 on prop roots. Ravikumar and Vittal (1996) also reported higher species numbers on prop roots of *R. apiculata* from Pichavaram mangroves, Tamil Nadu, on the east coast of India. The lower numbers of fungi recorded on some substrata may be due to the fact that these substrata are not favourable for fungal colonization. Another reason may be due to the collection of higher number of samples supporting sporulating fungi belonging to prop roots (2524) of *R. apiculata* and wood (1775) of *Avicennia* spp. than other substrata of the respective hosts. Hyde and Lee (1995) suggested that the diversity of marine fungi is greater in the tropics and attributed this to mangrove tree species richness and possibly the time spent on each study. Jones and Alias (1997) reported that the amount of substratum available for colonization is the overriding factor in determining fungal diversity. Collecting decomposing pneumatophores and roots of *Avicennia* spp. was not as easy as that of wood. Decaying prop roots of *Rhizophora* still attached to the host tree could easily be detached by hand, since they were decomposing. Wood samples of *R. apiculata* were less common as they have to be collected from uprooted trees or when growing on the tree, thus the number of decomposing wood samples found was far less. Similarly, availability of decomposing seedlings was also less as they easily get washed away. The thick cuticle around the seedlings may be one of the factors preventing fungal colonization.

Many species recorded in the present study on seedlings are new records for

this substratum. These are *Aniptodera mangrovei*, *Cirrenalia pygmea*, *Cryptosphaeria mangrovei*, *Dactylospora haliotrepha*, *Halocyphina villosa*, *Halorosellinia oceanica*, *Leptosphaeria australiensis*, *Lophiostoma mangrovei*, *Massarina velatospora*, *Massarina* sp., *Phomopsis mangrovei*, *Pedumispora rhizophorae*, *Periconia prolifica Saccardoella rhizophorae*, *Trichocladium achrasporum* and *Verruculina enalia*. No exclusive obligate marine fungi were restricted to seedlings. Twelve out of the 24 species found on seedlings were also commonly recorded on prop roots and wood and the rest were common to seedlings and prop roots of *R. apiculata*. Kohlmeyer and Kohlmeyer (1979) have drawn attention to the small number of obligate marine fungi (about 15), found on seedlings of *Rhizophora mangle* by Newell (1976). The present study substantially increases the number of marine fungi recorded on seedlings. This is true in the case of pneumatophores of *Avicennia* spp. also where few reports are available.

The percentage occurrence as an expression of the frequency of collections of fungi gives an indication of the more common fungi within the mangrove ecosystem (Hyde and Jones, 1988; Alias *et al.*, 1995). In the present study a comparison is made among very frequent, frequent and infrequent fungi on different substrata of *R. apiculata* and *Avicennia* spp. (Table 3). *Verruculina enalia* was recorded very frequently on all the three substrata of *R. apiculata*. However, its percentage occurrence was much less on prop roots (13.1%) in comparison to seedlings (23.7%) and wood (23.4%). Similarly, *Dactylospora haliotrepha* was very frequent on wood (12.5%), was frequent on prop roots (5.5%), and rare on seedlings (0.7%). On the other hand *Saccardoella rhizophorae* (17.6%) and *Phomopsis mangrovei* (18.3%) which were very frequent on seedlings, were infrequent on prop roots and absent on wood. *Lophiostoma mangrovei* was frequent on seedlings (8.1%) and wood (9.4%), but was infrequent on prop roots (1.5%). Such differences were also observed among the different substrata of *Avicennia*. *Verruculina enalia* was very frequent on all three substrata. However, its percentage occurrence was lower on pneumatophores (18.9%) than on roots (22.9%) and wood (24.7%). *Eutypa bathurstensis* was very frequent on wood, but was absent on the other substrata. *Leptosphaeria australiensis* very frequent on pneumatophores (11.7%), frequent on roots (5.1%) and rare on wood (0.6%). *Lulworthia* sp. was very frequent on roots (11%) and pneumatophores (12.6%) when compared with wood (4.1%) where it was infrequent.

Care should be taken in interpreting the results since there was no uniformity in the number of samples examined among the different substrata and a direct comparison of percentage occurrence of fungi may be misrepresentated. It is interesting, however, to note that each substratum, when seen individually, had its own very frequent, frequent and infrequent fungi appearing on them.

Table 3. Comparison of very frequent, frequent, and infrequent fungi recorded on different substrata of *Rhizophora apiculata* and *Avicennia* spp.

Host substratu	Very frequent	Frequent	Infrequent
Rhizophora apiculata			
Wood	*Verruculina enalia* (23.4) *Dactylospora haliotrepha* (12.5) *Hysterium* sp. (10.4)	*Lophiostoma mangrovei* (9.4) *Epicoccum purpurascens* (6.8) *Trichocladium achrasporum* (5.2)	*Massarina velatospora* (3.6) *Leptospaheria australiensis* (3.1) *Halorosellinia oceanica* (3.1) *Rhizophila marina* (2.6) *Hypoxylon* sp. (2.6) *Trimmatostroma* sp. (2.6) *Cryptosphaeria mangrovei* (2.1) *Aigialus grandis* (2.1) *Lulworthia* sp. (2.1) *Lecanidion atratum* (1.6)
Prop roots	*Verruculina enalia* (13.1) *Rhizophila marina* (11.7)	*Cirrenalia pygmea* (8.7) *Cryptospaheria mangrovei* (6.2) *Dactylospora haliotrepha* (5.5)	*Lulworthia* sp. (5) *Saccardoella rhizophorae* (4.7) *Halocyphina villosa* (3.8) *Halosarpheia abonnis* (3.3) *Epicoccum purpurascens* (2.7) *Trichocladium achrasporum* (2.5) *Massarina* sp. (2.4) *Phoma* sp. (2.3) *Leptospaheria australiensis* (1.9) *Trimmatostroma* sp. (1.9) *Halorosellinia oceanica* (1.7) *Halosarpheia ratnagiriensis* (1.7) *Periconia prolifica* (1.6) *Lophiostoma mangrovei* (1.5) *Aigialus grandis* (1.5)
Seedlings	*Verruculina enalia* (23.8) *Phomopsis mangrovei* (18.3) *Saccardoella rhizophorae* (17.6)	*Lophiostoma mangrovei* (8.1)	*Lulworthia* sp. (4) *Cirrenalia pygmea* (3.7) *Trichocladium achrasporum* (3.7) *Cryptospaheria mangrovei* (3.3) *Lulworthia grandispora* (2.9) *Phoma* sp. (2.9) *Halorosellinia oceanica* (2.6) *Halocyphina villosa* (1.5) *Alveophoma* sp. (1.5)
***Avicennia* spp.**			
Wood	*Eutypa bathurstensis* (25.9) *Verruculina enalia* (24.6)	*Lophiostoma mangrovei* (7)	*Halocyphina villosa* (4.5) *Lulworthia* sp. (4.1) *Hypoxylon* sp. (3.9) *Halorosellinia oceanica* (2.5) *Periconia prolifica* (2.4) *Dactylospora haliotrepha* (2) *Cryptovalsa* sp. (1.7) *Halosarpheia abonnis* (1.6)

Table 3. (continued).

Host substratu	Very frequent	Frequent	Infrequent
Pneumato-phores	*Verruculina enalia* (18.9) *Camarosporium roumeguerii* (17.1) *Lulworthia* sp. (12.6) *Leptosphaeria australiensis* (11.7)	*Bathyascus avicenniae* (8.1) *Zopfiella latipes* (7.2) *Halocyphina villosa* (5.4) *Lulworthia grandispora* (5.4)	*Savoryella lignicola* (4.2) *Mycosphaerella pneumatophorae* (2.7) *Periconia prolifica* (2.7) *Linincola longirostris* (1.8) *Hysterium* sp. (1.1) *Leptosphaeria peruviana* (1.1)
Pneumato-phores	*Verruculina enalia* (22.9) *Lulworthia* sp. (11) *Lophiostoma mangrovei* (10.2)	*Hypoxylon* sp. (9.3) *Halorosellinia oceanica* (8.5) *Halocyphina villosa* (5.9) *Leptosphaeria australiensis* (5.1) *Dactylospora haliotrepha* (5.1)	*Lulworthia grandispora* (4.2) *Halosarpheia marina* (4.2) *Camarosporium roumeguerii* (3.4) *Phoma* sp. (3.4) *Periconia prolifica* (1.7) *Aigialus parvus* (1.7) *Phomopsis* sp. (1.7)

It can be concluded that fungi colonizing mangrove substrata often show preference among different substrata of the same host (Ravikumar and Vittal, 1996).

Acknowledgements

The authors are thankful to the Ministry of Environment and Forests, Government of India for financial grant; to the Forest Department of East Godavari and Guntur districts for permission to collect samples from Godavari and Krishna detla mangroves respectively; to the Director, C.A.S. in Botany for facilities. V.V. Sarma is grateful to S. Raghukumar, National Institute of Oceanography, Goa, India for presubmission review and encouragement.

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(Received 16 September 1999, accepted 27 June 2000)