

Investigations on Fungal Parasites of Marine Algae in India : An Appraisal*

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Abstract

A survey of the Indian coast has been carried out to explore the presence of parasitic fungi in marine algae. Out of 35 filamentous algae examined 15 harboured fungal parasites. The percentage of algal cells infected in nature varied from < 5 to 60% for the different species. A total of 7 fungal genera belonging to Mastigomycotina, Labyrinthulales and Thraustochytriales were found regularly as parasites in various algae.

The various host parasite associations could be classified into three types.

- (1) Biotrophic parasites, host exhibiting no disease symptoms; e.g., *Chytridium polysiphoniae* in *Centroceras clavulatum* and *Sphacelaria* sp., *Coenomyces* sp. in species of *Cladophora* and *Rhizoclonium*.
- (2) Biotrophic parasites, host exhibiting severe disease symptoms; e.g., *Sirolopidium bryopsidis* in *Cladophora* spp., *Olpidium rostriferum* in *Cladophora* spp. and *Rhizoclonium* sp. and *Pontisma lagenidioides* in *Chaetomorpha media* and *Valoniopsis* sp.
- (3) Necrotrophic fungi; with the host affected variously; *Ulkenia visurgensis* and *Labyrinthula* sp. in various algae.

The seasonality of various host parasite associations were studied in four cases. In all cases maximum infection in nature occurred in the monsoon months of June-September. The fungal parasites exhibited host specificity. The results of these findings are discussed in light of information available.

Introduction

Fungal plant parasites play an important role in the terrestrial ecosystem (Dickinson and Lucas, 1982). One might expect that fungi are important as parasites of algae in the marine ecosystem also. Several such diseases have been reported. A few of these cause serious epidemics (Arasaki *et al.*, 1968; Kazama 1979; and Molina 1986). While on land intensive cultivation of crop plants gives rise to frequent epidemic proportions of fungal diseases, a similar situation has not arisen in the sea. However, when marine organisms are cultured on the commercial scale, the danger of serious outbreak of disease might occur. However, in natural stands of vegetation in the sea the incidence of diseases might be as common as on land. In order to investigate this a systematic survey along the Indian coast was taken up in the last four years. Based on these studies aspects of various host parasite combinations and their interactions are discussed.

*Dedicated to Dr. A. Gaertner, former Head of Botany Department, Institute für Meeresforschung, Bremer haven, W. Germany.

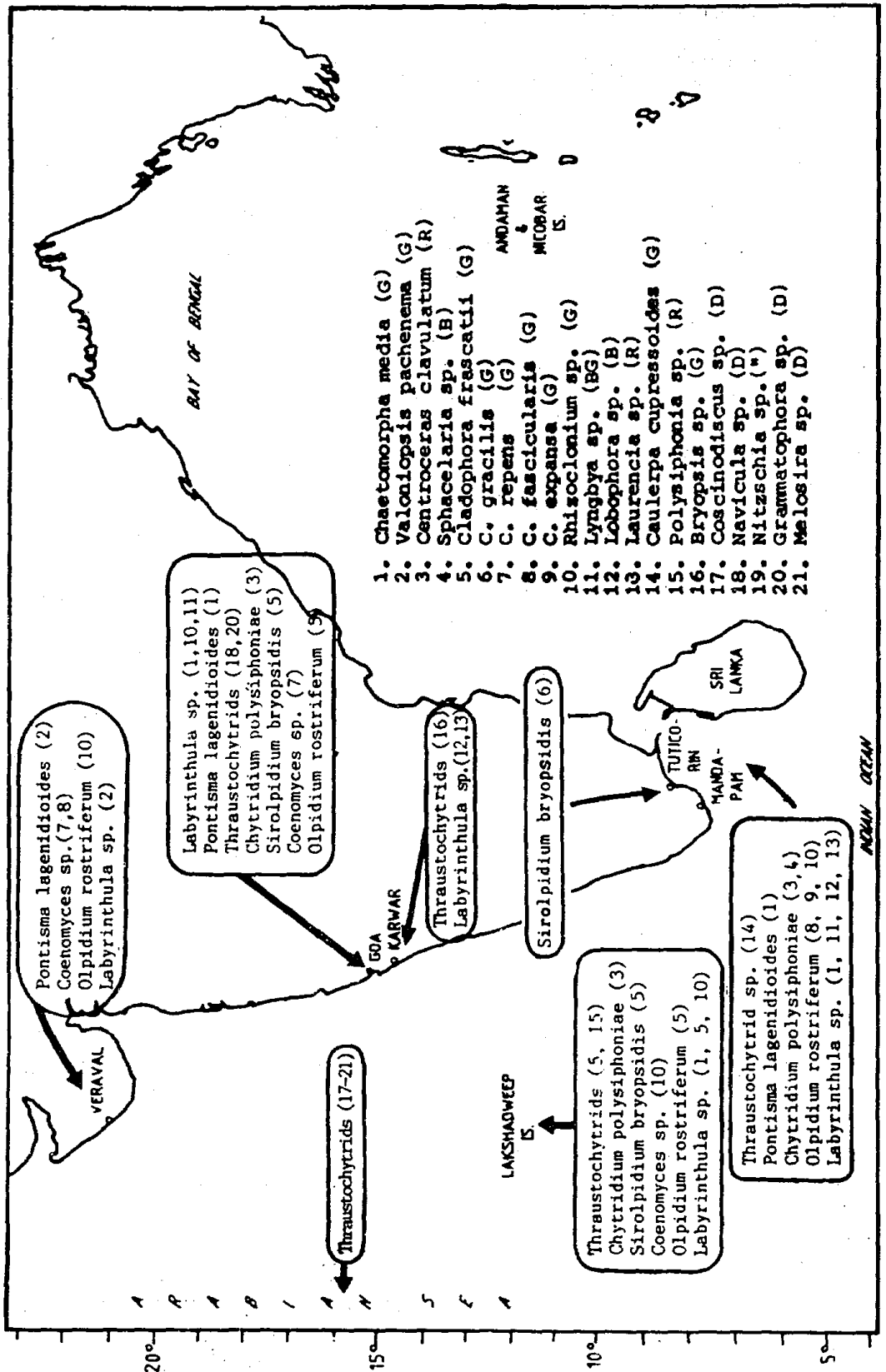


Fig. 1. Sampling sites along the Indian coast. Fungal parasites are listed in the map. Their hosts given as numbers in parenthesis. The algal hosts are listed below the map. G = green algae, B = brown algae, R = red algae, D = diatoms, BG = blue green algae.

Prevalence and Distribution of Fungal Diseases

All the sites sampled along the Indian coast revealed fungal parasites of marine algae (Fig. 1). Of the 35 species of filamentous algae examined 15 harboured parasitic fungi (Tables 1-5). Occurrence of parasites in particular species of algae might be influenced by season and locality. For example *Coenomyces* sp. and *Sirolopidium bryopsidis* in *Cladophora* sp. were not detected during some months. (Fig. 2) (Raghukumar, 1986 b). *Chytridium polysiphoniae* occurred in *Centroceros clavulatum* in some sites but not in others (Table 4). Therefore it is possible that the other 20 species of algae which revealed no parasites in the present study also harbour them in some seasons and localities. Several fungal parasites of filamentous algae have been reported by others (Sparrow, 1960; TeStrake and Aldrich, 1984; Aleem, 1950; Bott and Rogenmuser, 1980). Therefore, fungal parasites of filamentous algae appear to be common in nature.

Even if a disease occurs in nature, its severity may vary depending on the season. Examination of specimens immediately after collection revealed that the different diseases occurred at levels of < 5 to 60% (Fig. 2). Species of *Coenomyces*, *Olpidium*, *Sirolopidium* and *Chytridium* occurred at a greater percentage of infection than *Pontisma*, *Labyrinthula* and thraustochytrids in nature (Raghukumar, 1986 a, b, c, and 1987 a, b). Seasonal studies on the latter three have not been carried out. High percentage of infection of algae in nature has been reported by others also (Sparrow, 1960; Schatz 1984; Van der Meer and Pueschel, 1985). In those cases where the severity of diseases was low in nature, it could be enhanced by incubating the algae in sterile seawater in the laboratory (Raghukumar, 1987a, b).

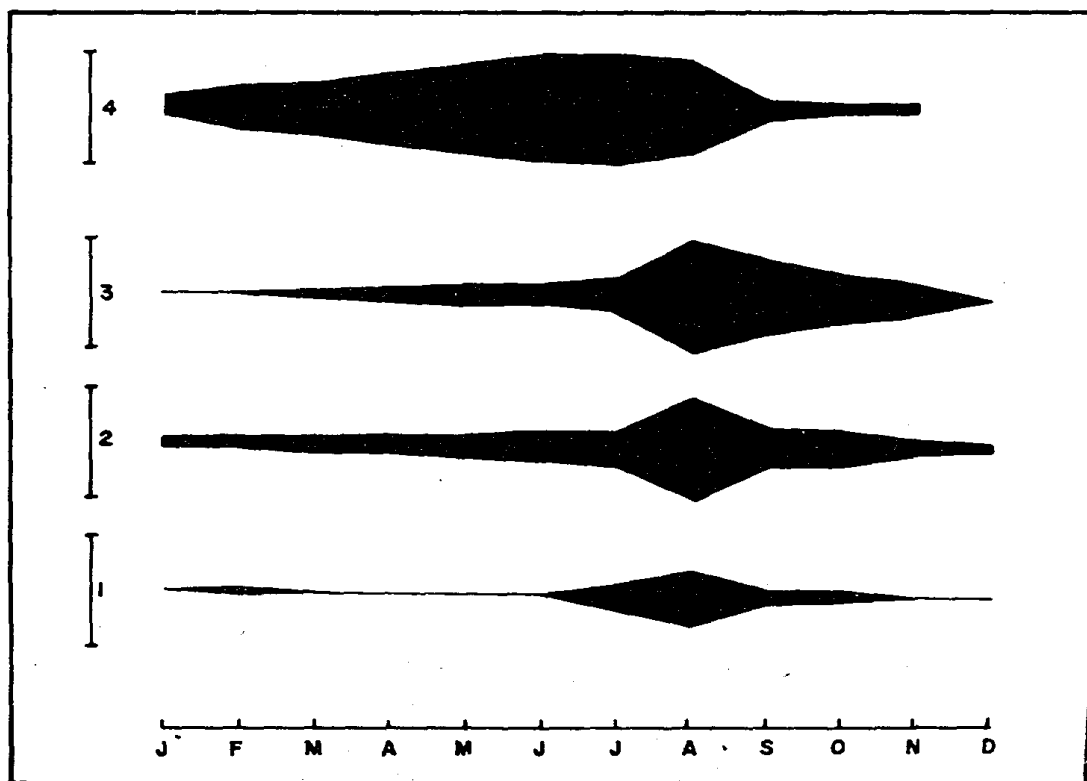


Fig. 2. Severity of infection by various fungal parasites in their respective algal hosts, in 1984. 1. *Coenomyces* sp. in *Cladophora repens*, 2. *Sirolopidium bryopsidis* in *C. frascatii*, 3. *Olpidium rostriferum* in *C. frascatii*, 4. *Chytridium polysiphoniae* in *Centroceros clavulatum*. Bars in 1, 2 and 3 represent 60% cell infection of the algal hosts. Bar in 4 represents 250 fungal sporangia in 25 internodes of the alga.

Table 1. Occurrence of *Labyrinthula* sp. in different algal hosts collected from various sites.

Algal host	Locality
<i>Cladophora frascatii</i>	Goa, Lakshadweep Islands
<i>C. repens</i>	Goa
<i>Rhizoclonium</i> sp.	Lakshadweep Islands, Mandapam
<i>Chaetomorpha media</i>	Mandapam (Tamil Nadu)
<i>Lyngbya</i> sp.	Mandapam
<i>Cladophora</i> sp.	Mandapam
<i>Lobophora variegata</i>	Mandapam
<i>Laurencia</i> sp.	Mandapam
<i>Valoniopsis pachenema</i>	Veraval (Gujarat)

Table 2. Occurrence of *Olpidium rostriferum* in various algal hosts collected from different sites.

Algal host	Locality
<i>Cladophora expansa</i>	Mandapam (Tamil Nadu)
<i>C. fascicularis</i>	Mandapam
<i>C. frascatii</i>	Goa, Lakshadweep Islands
<i>Rhizoclonium</i> sp.	Mandapam, Veraval (Gujarat)

Table 3. Occurrence of thraustochytrid on various algae and diatoms.

Algal host	Locality
Algae	
<i>Caulerpa cupressoides</i> (green alga)	Mandapam
<i>Polysiphonia</i> sp. (red alga)	Lakshadweep Islands
<i>Cladophora frascatii</i> (green algae)	Lakshadweep Islands
<i>Bryopsis</i> sp. (green alga)	Karwar (Karnataka)
Diatom	
<i>Coscinodiscus</i> sp.	Central Arabian Sea
<i>Navicula</i> sp.	Central Arabian Sea and Mandovi River
<i>Nitzschia</i> sp.	Central Arabian Sea
<i>Grammatophora</i> sp.	Central Arabian Sea
<i>Melosira</i> sp.	Central Arabian Sea and Mandovi River

Table 4. Fungal parasites and their algal hosts.

Algal host	Locality
<i>Coenomyces</i> sp. (Association, no symptoms)	
<i>Cladophora repens</i>	Goa
<i>C. fascicularis</i>	Veraval (Gujarat)
<i>Rhizoclonium</i> sp.	Lakshadweep Islands
<i>Chytridium polysiphoniae</i> (epiphytic)	
<i>Centroceras clavulatum</i> (red alga)	Goa, Mandapam, Lakshadweep Islands
<i>Sphacelaria</i> sp. (brown alga)	Mandapam

Seven marine fungi belonging to Mastigomycotina, Labyrinthulales and Thraustochytriales were repeatedly found as parasites in different algae (Fig. 1, Tables 1-5). *Labyrinthula* sp. was the most common parasite. Out of 17 species of algae which harboured parasites, 9 were infected by *Labyrinthula* sp. (Table 1). *Olpidium rostriferum* occurred in 4 out of 17 species (Table 2). The Thraustochytrid, *Ulkenia visurgensis* was found on 9 species of algae (Table 3).

Table 5. Fungal parasites and their algal hosts.

Algal host	Locality
<i>Sirolopidium bryopsidis</i> (Terminal browning)	
<i>Cladophora frascatii</i>	Goa, Lakshadweep Islands
<i>C. gracilis</i>	Tuticorin
<i>Pontisma lagenidioides</i> (Browning disease)	
<i>Chaetomorpha media</i>	Mandapam, (Tamil Nadu), Goa
<i>Valoniopsis pachenema</i>	Veraval (Gujarat)

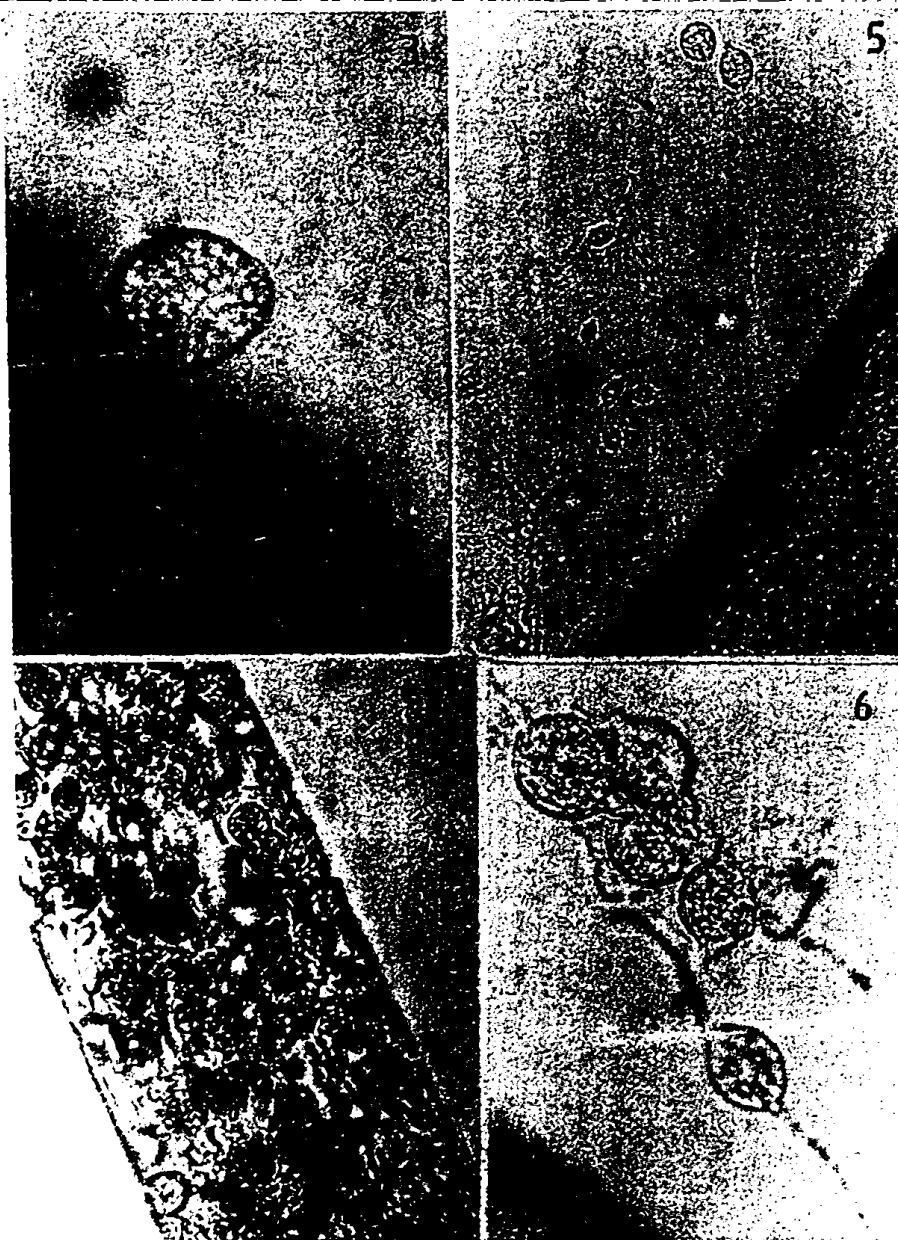
Fig. 3. Mature sporangium of *Chytridium polysiphoniae* on *Centroceras clavulatum*. x 800Fig. 4. Sporangia of *Coenomyces* sp. embedded in *Cladophora repens*. x 450Fig. 5. Sporangia of *Coenomyces* sp. emerging out of its algal host. x 450

Fig. 6. The same at x 1100

Types of Host Parasite Relations

The associations between the various fungal parasites and their hosts could be categorized as follows.

[I] Fungi biotrophic; host exhibiting no disease symptoms

The epiphytic chytrid *Chytridium polysiphoniae* Cohn occurred on the red alga *Centroceras clavulatum* (C. Agardh) Montagne and the brown alga *Sphacelaria* sp. This fungus produced monocentric urn shaped sporangia (Fig. 3) and uniflagellate zoospores (Raghukumar, 1986a, 1987). Both the algae showed no symptoms of disease.

The green alga *Cladophora* and *Rhizoclonium* also did not reveal any disease symptoms when infected by the polycentric chytrid *Coenomyces* sp. (Table 4). This fungus produced endo and epiphytic thallus. The fungal thallus remained mostly buried inside the algal host, (Fig. 4), but on incubation in sterile seawater the hyphae bearing sporangia emerged out (Figs. 5, 6) (Raghukumar, 1986 b).

In both these cases the fungi apparently draw nutrients from the host without damaging it. Both these fungi could be maintained only on living hosts and not on killed algae. They could not be cultured on any natural or synthetic media in the laboratory. *Blodgettia bornetii*, a mycelial fungus has been reported to grow between the lamellae of *Cladophora* cell wall without causing any damage to the host (TeStrake and Aldrich, 1984). Kohlmeyer (1974) termed this mycophycobioses.

[II] Fungi biotrophic, host exhibiting severe disease symptoms

Three biotrophic parasites are known from Indian coast (Raghukumar, 1986 b, 1987a) (Tables 2 & 5). These parasites caused varying degrees of browning in their respective hosts. *Sirolopidium bryopsidis* (De Bruyne) H. E. Peterson, caused browning of terminal cells of various species of *Cladophora*. The fungal sporangia occupied the entire cell (Fig. 7).

Olpidium rostriferum Tokunaga caused browning of cells in species of *Cladophora* and *Rhizoclonium* (Raghukumar, 1986b, 1987a). This fungus was more devastating since it killed almost all the cells (Fig. 8). *Pontisma lagenidioides* caused severe browning disease of *Chaetomorpha media* (C. Agardh) Kutzing (Raghukumar, 1987a). The cells show a gradual browning from tip downwards. The algal cells become filled with number of fungal sporangia (Fig. 9, 10, 11 and 12). The infected filaments turn completely brown and start fragmenting in severely diseased plant. There is a loss in fresh weight on infection (Fig. 13).

In all these diseases there is a loss in chlorophyll content and accumulation of phaeopigments. This has been studied in the laboratory in *Chaetomorpha-Pontisma* (Fig. 14). None of the parasites could be grown on dead algae or in synthetic media.

Parasitic fungi which cause total destruction of their hosts have been reported (Sparrow, 1960; Kazama, 1979; Raghukumar, 1978; Schnepf *et al.*, 1978; Grahame, 1976).

[III] Necrotrophic fungi, host may or may not exhibit symptoms

Raghukumar (1986 c) reported the thraustochytrid *Ulkenia visurgensis* (Bahnweg and Sparrow) Gaertner, on many diatoms collected from the central Arabian sea (Table 3). This organism grew on decaying cultures of diatoms and also grows on living algal filament (Figs. 15, 16). The fungus did not cause any change in the morphology of alga and could be grown on pine pollen in seawater.

A species of *Labyrinthula* was observed to be a serious pathogen of several filamentous green algae (Table 1). The infected algal cells are filled with spindle shaped cells of the fungus (Figs. 17, 18). It caused discolouration of chloroplast, accumulation of brown pigments (the breakdown product of chlorophylls), loss in weight and resulted ultimately in the death of the affected cells.

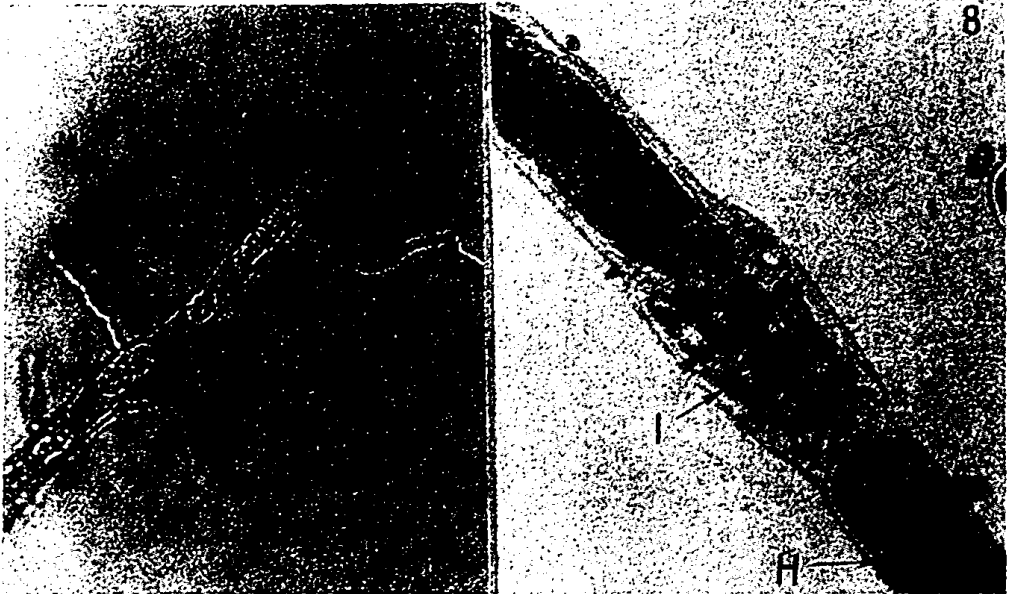


Fig. 7. *Sirolopidium bryopsidis* sporangia in a terminal cell of *Cladophora frascatii*. Note the long discharge tubes of fungal sporangia emerging out of the algal cell wall. x 250.

Fig. 8. *Olopidium rostriferum* in *Cladophora frascatii*. H = healthy cell, I = infected cell x 400

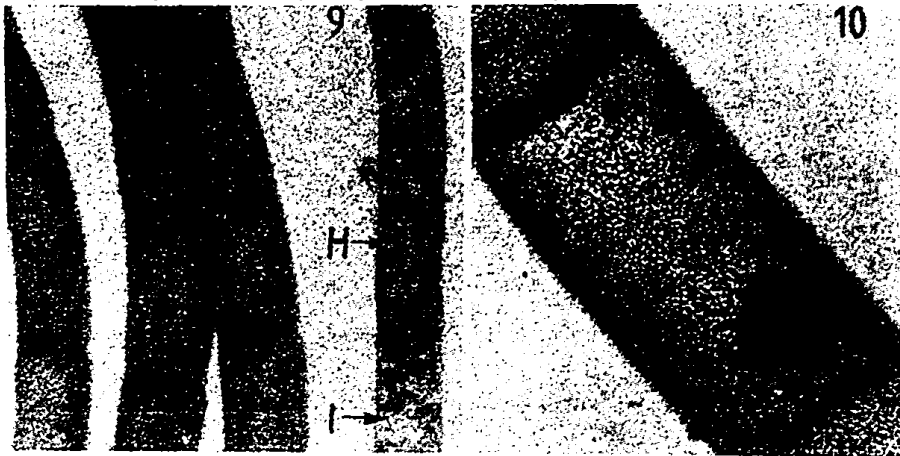


Fig. 9. *Chaetomorpha media* showing infected cell. x 30

Fig. 10. Initial stages of infection in the cell of *Chaetomorpha media* (arrow). The chloroplast is still intact x 80.

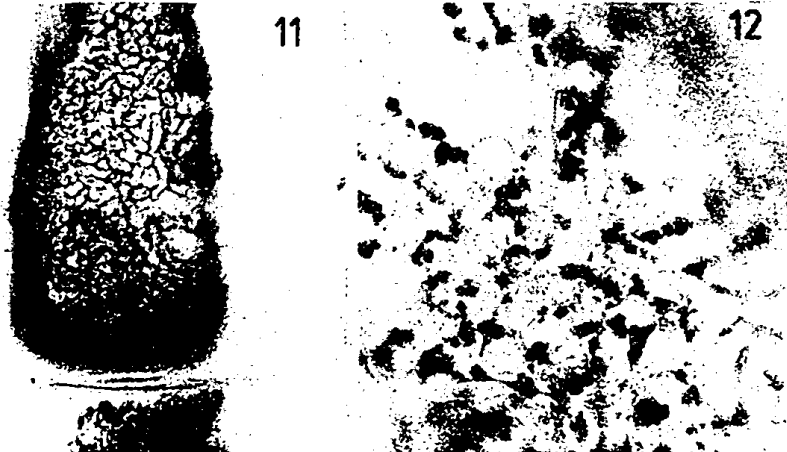


Fig. 11. Cell of *C. media* completely filled with fungal sporangia (arrow). The host chloroplast is destroyed. x 80

Fig. 12. A portion of fungal sporangia enlarged. Note the breakdown product of chlorophyll accumulated as dark granules along the fungal sporangial walls (arrow). x 300

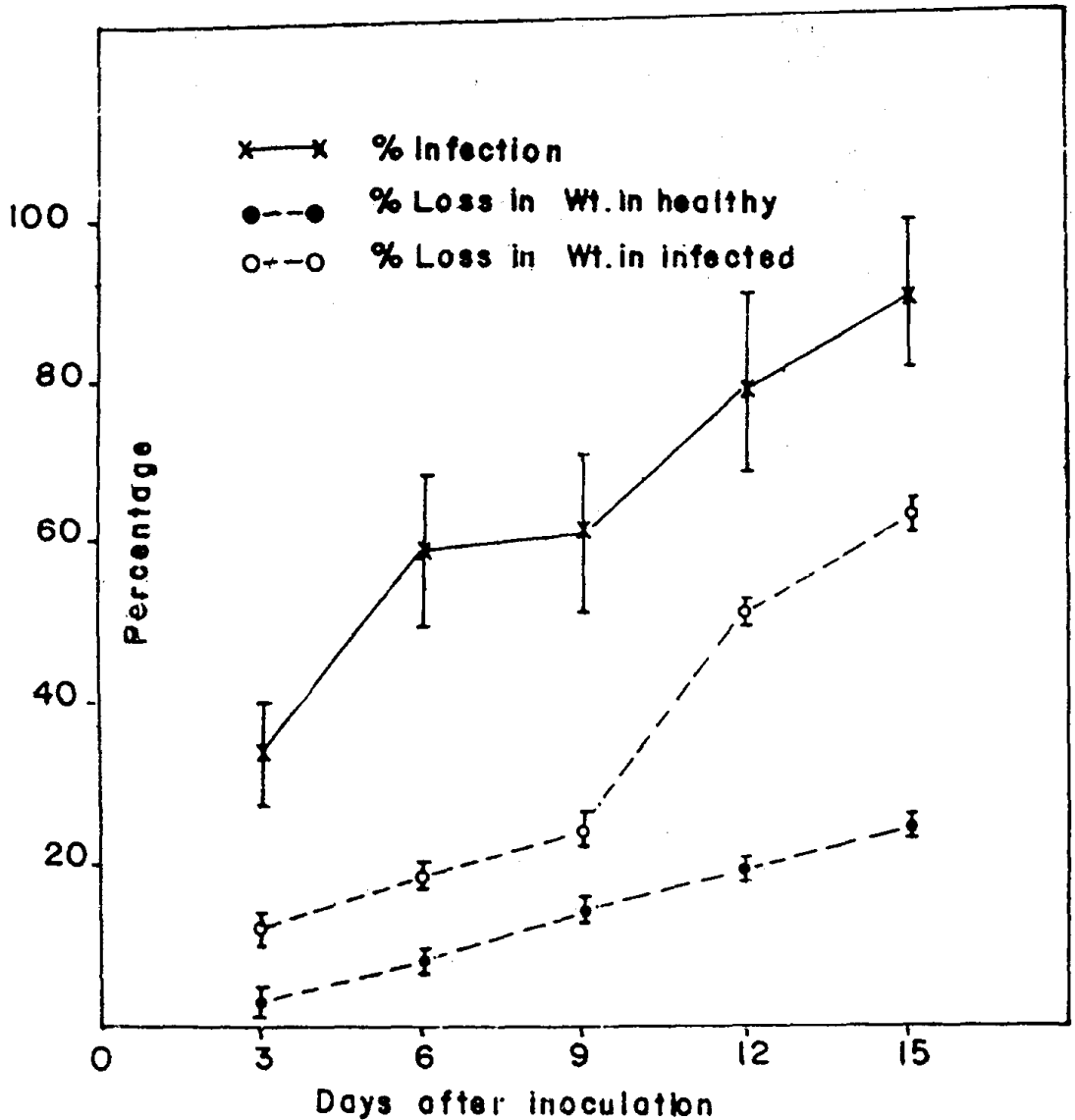


Fig. 13. Percentage of algal cells infected in *Chaetomorpha media* by *Pontisma lagenidioides* and also loss in weight of the alga on infection (with permission from *Dis. aqua. Org.*)

It could be grown on killed algal filaments and also on pine pollen in seawater. This organism has also been isolated from algal hosts where it did not cause any apparent damage to the host (Fig. 19).

Thraustochytrids and Labyrinthulids can be easily isolated from decaying organic matter in the sea. They have been reported also as parasites by others. Gaertner (1979) reported disintegration of live diatom cells by a thraustochytrid. *Labyrinthula* sp. was suspected to be the causal agent for the wasting disease of eel grass (Rasmussen, 1977).

Seasonal Occurrence of the Diseases

The seasonality of four host parasitic associations have been studied. These are:

- (1) *Chytridium polysiphoniae* on *Centroceros clavulatum* (Raghukumar, 1986a).
- (2) *Coenomyces* sp. in *Cladophora repens* (Raghukumar, 1986b)
- (3) *Olpidium rostriferum* in *Cladophora frascatii* (Raghukumar, 1986b)
- (4) *Sirolpidium bryopsidis* in *Cladophora frascatii* (Raghukumar, 1986b).

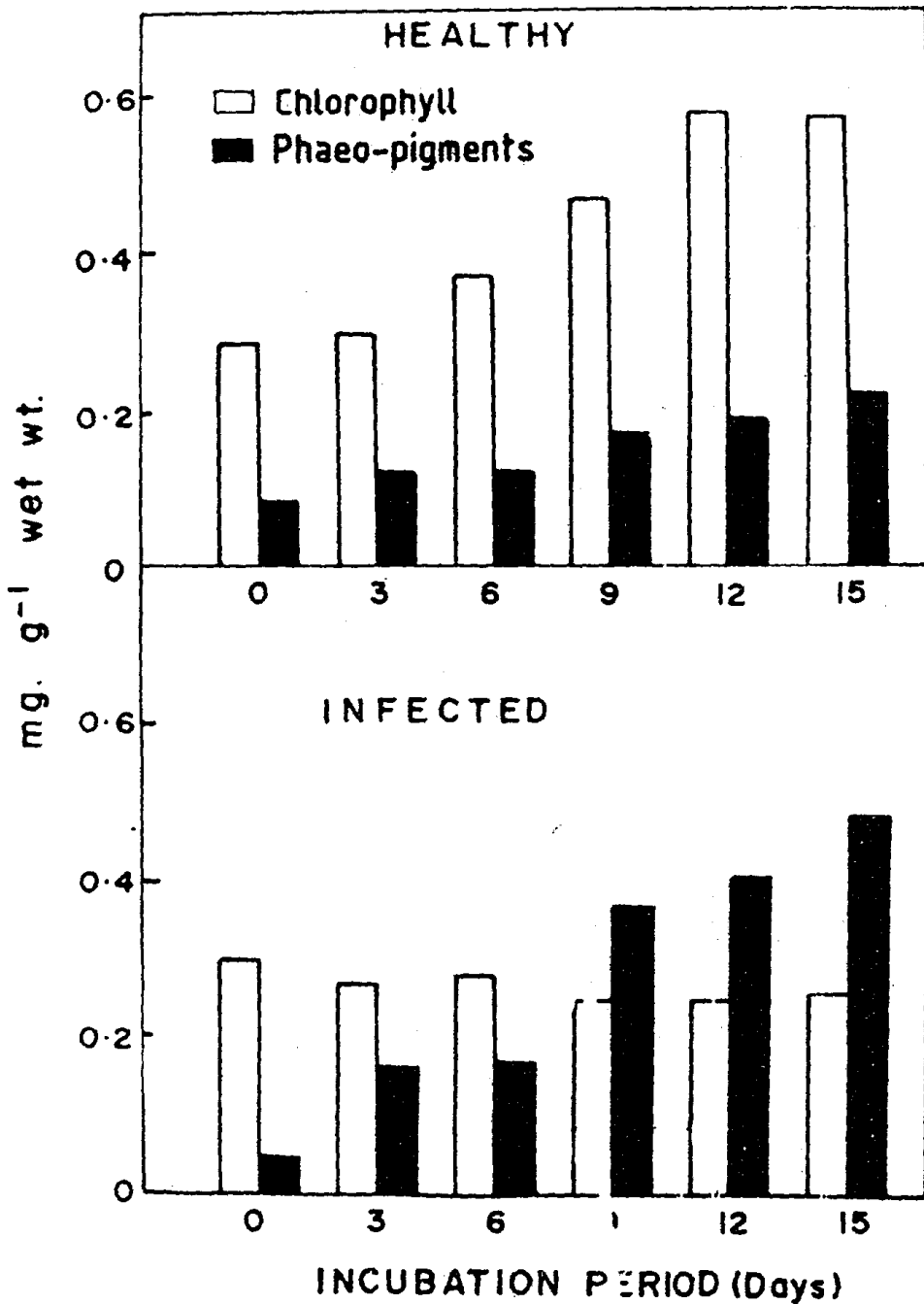


Fig. 14. Loss of chlorophyll and accumulation of phaeopigments in *Chaetomorpha media* inoculated with *Pontisma lagenidioides* (Laboratory studies).

Maximum infection in all these cases occurred during south west monsoon period of June-September in Goa (Fig. 2). It is possible that the high amount of nutrient influx from land and/or the lower salinity conditions favoured infections. Future laboratory studies will have to confirm this.

Based on these studies three possibilities of the effect of season on host parasite could be envisaged.

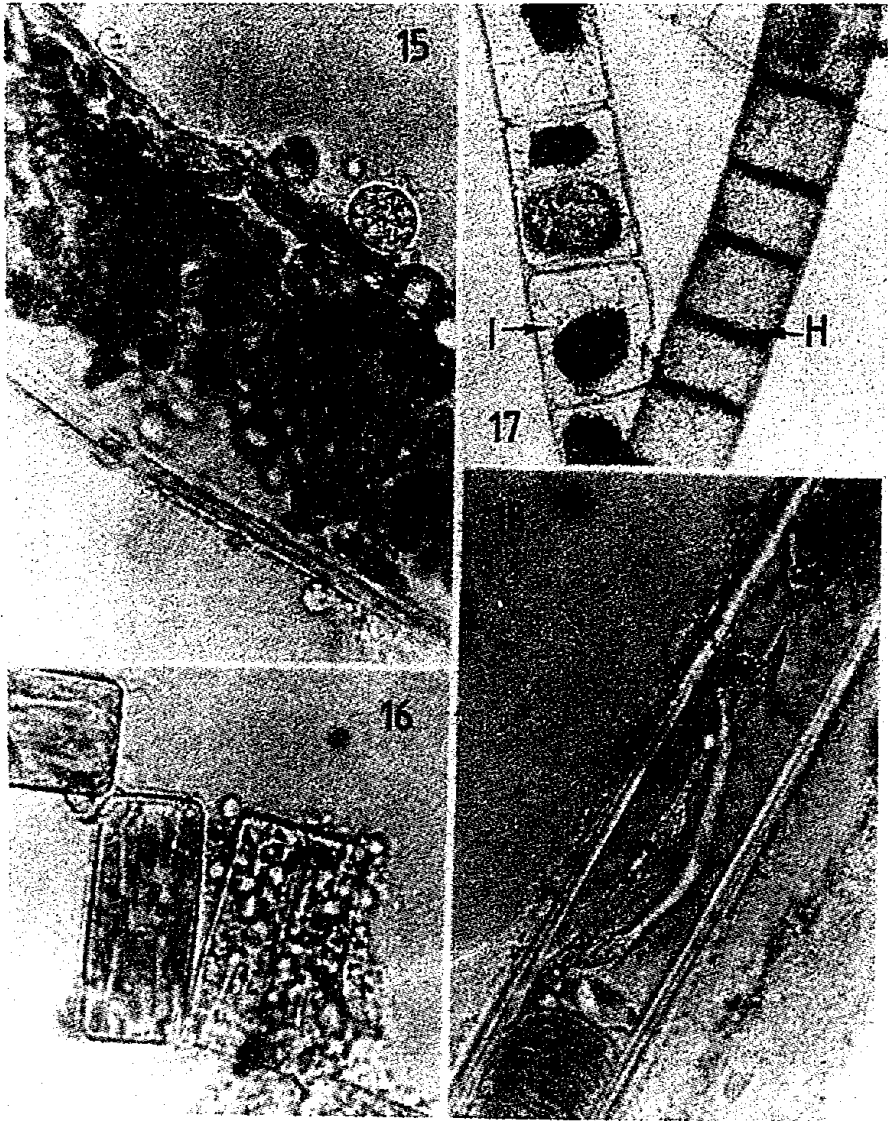


Fig. 15. *Ulkenia visurgensis* on *Cladophora* sp. x 1000

Fig. 16. Same on the diatom *Grammatophora* sp. x 1000

Fig. 17. *Labyrinthula* sp. in the green alga *Rhizoclonium* sp. H = healthy filament, I = infected filament x. Note the spindle shaped cells of the fungus. x 325

Fig. 18. *Labyrinthula* sp. in the blue green alga - *Lyngbya* sp. x 800

- (1) As mentioned earlier *Coenomyces* sp. and *Chytridium polysiphoniae* are biotrophic parasites and do not affect the hosts seriously. When the seasonal conditions are unfavourable to the host, these fungi will also be affected. These genera might produce resting spores. It is worthwhile investigating the behaviour of these fungi in nature.
- (2) The biotrophic parasites *Sirolopidium bryopsidis*, *Olpidium rostriferum* and *Pontisma lagenidioides* are capable of causing severe disease in their respective hosts. Between June-September the infection by the first two fungi in their respective hosts amounted to about 60%. It is possible that such parasites themselves are responsible for the seasonal disappearance of their host species. The biotrophic parasite *Ectrogella perforans* in the marine diatom *Licmophora* sp. (Sparrow, 1960) and other chytrids in fresh water diatoms (Canter and Lund, 1951) have been reported to affect the periodicity of

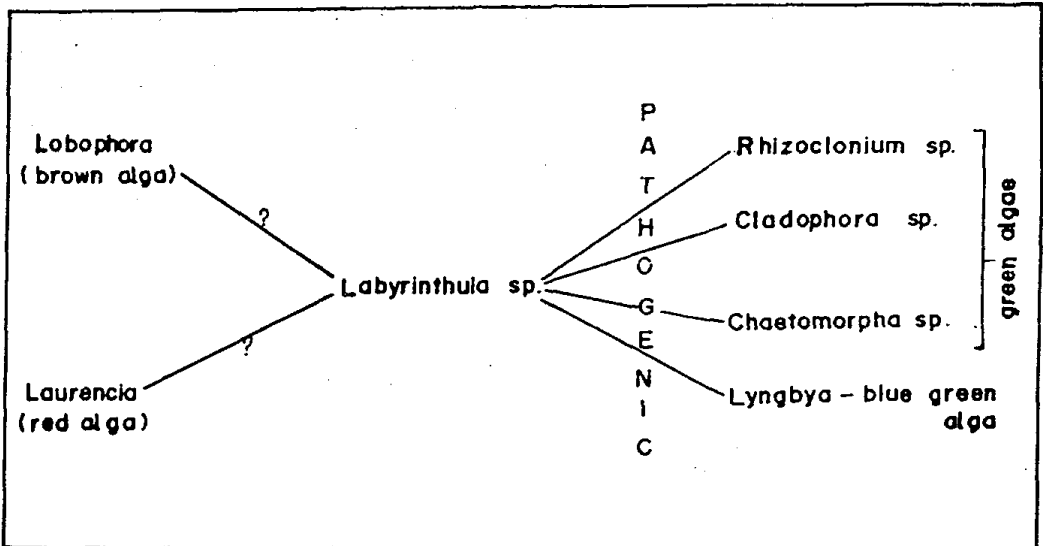


Fig. 19. Occurrence and pathogenicity of *Labyrinthula* sp. in different algae.

diatoms. These single celled host and parasite associations offer an excellent opportunity to study the host parasite interactions at cellular and biochemical levels (Raghukumar, 1980a, b, 1983). They can be quite devastating since they complete their life cycle in the host cell and rapidly spread to the next cell (Raghukumar, 1978).

- (3) The necrotrophic parasites, *Ulkenia visurgensis* and *Labyrinthula* sp. are apparently opportunistic parasites not severely affected by the seasonality of their hosts.

Host Specificity

The parasite in *Cladophora frascatti* and *C. gracilis* corresponded in its morphological characters to *Sirolopidium bryopsidis* (Sparrow, 1960). Sparrow reported it on *Bryopsis* and *Cladophora* sp. However in our cross inoculation studies, a few other species of *Cladophora* could not get infected by *S. bryopsidis*. *Olpidium rostriferum* occurred in *Cladophora frascatii*, *C. expansa*, *C. fascicularis* and *Rhizoclonium* sp. It was reported on zygospores of *Spirogyra* (Sparrow, 1960). Once again inoculation studies using species of *Cladophora* other than that in which it naturally occurred proved futile (Raghukumar, 1986b). *Pontisma lagenidioides* originally reported on *Ceramium* (Sparrow, 1960) occurred in India in *Chaetomorpha media* and *Valoniopsis* sp. but would not infect *Chaetomorpha linum* (Raghukumar, 1987 a). Therefore there is no predictability of their host preferences although host preferences do exist. An important question remains about their taxonomy. Are these geographically widely distributed species, occurring in different hosts all identical or not? Taxonomic studies on this difficult group of obligately parasitic phycomycetes is urgently required.

Chytridium polysiphoniae could be cross inoculated from the red alga *Centrocerus clavulatum* to *Sphacelaria* sp. a brown alga and vice versa. *Labyrinthula* exhibited a wide range of hosts (Fig. 19), behaving as severe pathogen in some and as weak parasite in others.

Of the various algal genera examined species of *Cladophora* harboured the maximum number of parasites (Tables 1-7). *Coenomyces* sp., *Olpidium rostriferum*, *Sirolopidium bryopsidis* and *Labyrinthula* sp. were very common in species of this genus. The reason for this is not understood at this moment.

Laboratory studies of most of these diseases is made difficult by the fact that the fungi involved are biotrophs and cannot be cultured in laboratory media. Therefore such fungal parasites and their host algae have to be maintained in dual cultures. Nutritional studies to enable these organisms to be cultured in the laboratory are urgently required.

Research in this field has implications in biological control of fouling algae. A search for biological control of algae has been carried out by some workers (Redhead and Wright, 1978; Bott and Rogenmuser, 1980). *Labyrinthula* sp. could be a suitable candidate organism to initiate biological control of some of the nuisance algae. However, an ideal organism for this purpose would be fast growing culturable filamentous fungus which should also be a necrotroph. It should be capable of producing extracellular lytic enzymes or toxins which could damage or kill the host in advance.

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