impact of land management practices. The effectiveness of the 'off the shelf' technologies like biotechnology as well as other modern technologies (remote sensing, geographic information systems, etc.) in developing countries crucially depends on educated farmers.

It would be naïve to suggest that biotechnology will solve the food problem, but there is clear evidence that it provides a technical platform to certain problems and should be adopted. Experiments at The Energy and Resources Institute, New Delhi underline that biotechnology is based on a solid institutional framework, including extensive capacity building in agricultural research and technology diffusion. Only in this way can the potential gains from biotech-derived products reach small-scale farmers in a sustainable manner.

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Mangrove fungi in India

Mangroves are coastal wetland forests established at the intertidal zones of estuaries, backwaters, deltas, creeks, lagoons, marshes and mudflats of tropical and subtropical latitudes. Approximately one-fourth of the world's coastline is dominated by mangroves that are distributed in 112 countries and territories comprising a total area of about 181,000 km^2. Among the marine ecosystems, mangroves constitute the second most important ecosystem in productivity and sustained tertiary yield after coral reefs[1]. Mangrove plants have morphologically and physiologically adapted to habitats with high salinity, tidal inundation, high wind velocity, high temperature and anaerobic clayey soils. These forests are of great ecological importance, social significance and economic value. Mangrove forests generate considerable amount of detritus such as leaf litter, woody debris and inflorescence and hence constitute an ideal environment for many detritus-dependent fauna and microbes. Productivity in mangrove waters depends on the extent of mangrove canopy cover that supplies carbon, nitrogen and phosphorous. The Indian peninsula comprises approximately 7000 km^2 of mangroves, out of which 70, 18 and 12% exist at the east coast, Andaman and Nicobar Islands, and west coast respectively[2].

Based on plant/fungus ratio, Hawksworth[3] estimated the world's fungal resource as 1.5 million species. Since then, several postulations guessed fungal population between 0.5 million[4] and 9.9 million[5] species. On published estimates, Hawksworth[6] reassessed up to 5.1 million fungal species. Plant/fungus ratio has been predicted as 1 : 6 in temperate locations[3]. Investigations on palm fungi in Queensland revealed a ratio of 1 : 26 in the tropics[7] and it was revised to 1 : 33 based on palm fungi in Australia and Brueni Darussalam[8]. Mangroves being detritus-based ecosystems, substantial fungal populations are involved in detritus processing. Studies revealed that mangrove fungi are the second largest group among the marine fungi. About 40% of existing mangrove forests has been depleted in India by human interference (agriculture, aquaculture, irrigation, industry and fuel wood extraction), which has resulted in increased erosion and decline in fishery resources[2]. Due to continued human interference and depletion of mangrove habitats, dangers of losing some precious fungal resources cannot be ruled out, as many are habitat- and/or host-specific. The present pattern of assessment of higher fungi in the mangrove ecosystem is biased towards assessment of typical marine fungi and the rest (e.g. terrestrial fungi) are ignored.

The season in which detritus are recovered from the mangroves decides fungal composition. Monsoon begins in the southwest coast of India in late May or early June and continues up to September. Heavy rainfall in the Western Ghats results in flushing freshwater and sediments to mangrove habitats and salinity declines to zero. During post-monsoon until January, salinity rises up to 50% (i.e. 17.5‰)[9]. This facilitates colonization of freshwater fungi on mangrove substrates during the rainy season[9]. Live and dead twigs of mangrove canopy harbour terrestrial fungi; when such substrata get into mangrove waters during monsoon, these fungi dominate at least for a few months[10]. Endophytic fungi of mangrove leaves, stems and roots consist of more terrestrial than marine fungi[11,12]. Even after 12 months of immersion of wood in the mangroves, anamorphic fungi dominated during the subsequent monsoon[10]. In mangrove habitats, at least up to six months under low saline conditions, freshwater and terrestrial fungi are involved in litter decomposition. During summer (February–May), increased salinity mainly supports marine fungi on detritus. Core group fungi (≥ 10% frequent) on woody debris that differ between the west and east coast of India, may be due to the difference in diversity of mangrove plant species[13]. Conditions prevailing in the mangroves of the Indian peninsula need not necessarily be similar to those at other parts of the world. Hence composition of mangrove mycoflora varies substantially, although they fall at the same latitude.

Techniques of assessment of substrata have a significant role in the occurrence of fungi[11]. Plating methods usually result in isolation of terrestrial fungi[14], damp-incubation helps to recover marine and terrestrial fungi and bubbling-chamber incubation facilitates recovery of freshwater hyphomycetes[9,11]. All these methods help in the exploration of mangrove filamentous fungi. Evaluation of fungi on substrata usually depends on production of fungal reproductive structures. Duration of incubation of substrata and observation intervals in the laboratory are important to assess diversity of mangrove fungi. Incubation of leaf detritus up to eight weeks results in dominance of terrestrial fungi and decline thereafter[15]. Sporulating marine fungi reach a peak usually during 16 weeks, while arenicolous (sand-inhabiting) fungi appear after 16 weeks of incubation[15]. Screening incubated mangrove substrata once in two weeks is necessary for a reasonable assessment of filamentous fungi[10]. If the interval of observation is too long, many sporulating anamorphic taxa disappear.

Many fungi are host-specific; if the host plant is endemic, its fungal component will also have restricted distribution. Loss of endemic plants results in total elimination of host-specific fungi from the ecosystem. For instance, among the mangroves of peninsular India, *Kandelia candel* (Rhizophoraceae) has been recorded only in two locations of the west coast of India (River Kollur, Havadu; River Gurupur, Bangrakular, Mangalore)[16]. Similarly, *Heritiera fomes* (Sterculiaceae) and *Nypa fruticans* (Palmaceae) found in Sunderbans are unknown elsewhere in India[16]. So far, no studies are available on the fungal components or association with these hosts in India. Mangrove ecosystems support many food webs and animal remains also accumulate (e.g. crab exoskeletons, bird feathers and calcareous shells). Fungal components of animal substrata in mangroves have not drawn much attention of mycologists. Long-term incubation is necessary to have a clear picture of fungi that exploit animal remains[17].

Data on litter input and pattern of its turnover in Indian mangroves are insufficient. Unless accurate data on canopy cover and litter input are available, it is difficult to link the extent of mangrove vegetation or its canopy cover and rate of detritus turnover with that of mangrove productivity. Mangroves of Mandovi–Zuari estuarine system, Goa have been studied for litter fall and energy influx. A similar study has been carried out on Pichavaram mangroves in the east coast of India. It is reasonable to expect many micro- and macroecological niches in mangroves that harbour different kinds of mycota. Senescent mangrove leaves detached from plants reach distinct habitats: (a) they may be entrapped above water level in the canopy or regions which are not accessible to tides, dry and reach the water due to storm or wind; (b) float on the surface of water (as dry or fresh) during high tides; (c) reach mangrove floor during low tides; (d) they may be entrapped at some depth below the water surface; (e) settle on sediment or be trapped in sediment. Similarly, dried twigs detach due to heavy rains during monsoon, entangle in the canopy or enter the water column (with or without bark) or settle on the floor or get entrapped in sediment. Dead stems, proproots and pneumatophores may decay, although attached to plants. These conditions determine the type of fungus and its activities on leaf or woody litter or attached decaying parts. Oomycota as well as Eumycota are involved in the turnover of mangrove detritus. In fact, Oomycota uses 'substrate capture' strategy, while Eumycota the 'mass accumulation' strategy[18]. Newell and Fell[19] pointed out that if litter is floating, it is swiftly colonized by halophytophthoras, while on leaves covered by bacterial films, colonization of halophytophthoras will be blocked. Newell and Fell[19] suspected intermittent drying of mangrove leaf litter results in high eumycotic activity. Such a situation may be applicable to partially wet leaf litter on mangrove floor. Under appropriate environmental conditions (e.g. intermittent drying), Eumycota compete with halophytophthoras[20].

Irrespective of assumptions, hypotheses and controversies on the occurrence of terrestrial fungi in marine habitats, detritus-driven mangrove ecosystem is influenced by a consortium of marine, freshwater and terrestrial fungi. Even though mangroves constitute major productive ecosystems in India, their fungal resources and diversity have not been explored adequately. Habitat of detritus, sampling season, methods of assessment, detritus incubation period and intervals of detritus screening require special attention to explicitly document mangrove-inhabiting fungi. Besides leaf and woody litters, animal remains have to be explored for fungal biota. Endophytic fungi of mangroves are less explored and hence deserve special attention. Studies on patterns of litter input, decomposition and turnover in mangroves need to be addressed.

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