Fungal Biology

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Fungal diversity, ecology and control management

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Fungal Biology

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Fungal biology has an integral role to play in the development of the biotechnology and biomedical sectors. It has become a subject of increasing importance as new fungi and their associated biomolecules are identified. The interaction between fungi and their environment is central to many natural processes that occur in the biosphere. The hosts and habitats of these eukaryotic microorganisms are very diverse; fungi are present in every ecosystem on Earth. The fungal kingdom is equally diverse, consisting of seven different known phyla. Yet detailed knowledge is limited to relatively few species. The relationship between fungi and humans has been characterized by the juxtaposed viewpoints of fungi as infectious agents of much dread and their exploitation as highly versatile systems for a range of economically important biotechnological applications. Understanding the biology of different fungi in diverse ecosystems as well as their interactions with living and non-living is essential to underpin effective and innovative technological developments. This series will provide a detailed compendium of methods and information used to investigate different aspects of mycology, including fungal biology and biochemistry, genetics, phylogenetics, genomics, proteomics, molecular enzymology, and biotechnological applications in a manner that reflects the many recent developments of relevance to researchers and scientists investigating the Kingdom Fungi. Rapid screening techniques based on screening specific regions in the DNA of fungi have been used in species comparison and identification, and are now being extended across fungal phyla. The majorities of fungi are multicellular eukaryotic systems and therefore may be excellent model systems by which to answer fundamental biological questions. A greater understanding of the cell biology of these versatile eukaryotes will underpin efforts to engineer certain fungal species to provide novel cell factories for production of proteins for pharmaceutical applications. Renewed interest in all aspects of the biology and biotechnology of fungi may also enable the development of “one pot” microbial cell factories to meet consumer energy needs in the 21st century. To realize this potential and to truly understand the diversity and biology of these eukaryotes, continued development of scientific tools and techniques is essential. As a professional reference, this series will be very helpful to all people who work with fungi and should be useful both to academic institutions and research teams, as well as to teachers, and graduate and postgraduate students with its information on the continuous developments in fungal biology with the publication of each volume.

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Preface

Food security is one of the major concerns in the world today. The continuously increasing world population coupled with global climate change poses a grave challenge to feed a billion mouths. Fungi play a significant role in modulating plant's environment, in both rhizosphere and phyllosphere resulting in growth changes that affect agricultural productivity significantly. Fungi have serious consequences on food security in the changing global environmental scenario.

Fungi play key roles in the ecosystem as decomposers, mutualists and pathogens and represent the second most diverse group after insects. Fungal diversity is not only reflected in its morphological characters but also in bioactive molecules produced, their pathogenicity and virulence, and impact on crop production. The increasing number of infectious fungal diseases is regarded as a global threat to agricultural productivity and food security. Therefore, it is important to document the fungal diversity and inventorize it. Further, to sustain agricultural productivity, it is important to mitigate or control the plant diseases. Plant pathogens cause severe losses to crops and significantly reduce the quality and quantity of agricultural products. The global tendencies are shifting towards a preferred use of various biocontrol agents in plant disease management. Fungal antagonists are widely used as biocontrol agents to control plant diseases globally. Biological control mechanism, however, needs an understanding of the complex interactions among plants, pathogens, and the environment.

This book provides a consolidated and comprehensive account of research being conducted by scientists all over the world in the areas of fungal biodiversity, fungal ecological services, fungal biology and ecology, and biological disease control and provides perspectives on crop protection and management and control of various fungal pathogens. The book also serves as an invaluable resource for researchers and educators working in the above fields. It will be useful to students studying mycology, plant pathology, crop protection, agricultural sciences, and plant sciences. Students will find this book handy to clear their concepts and to get an update on the recent research conducted in this area. Also, scientists involved in biological and agricultural research, crop management and environmental sciences and industries that manufacture agrochemicals as well as small- to large-scale growers and producers will find the book useful.

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The editors gratefully acknowledge their families for their understanding, patience, and emotional support during the course of this book. Our sincere thanks are due to the whole Springer team involved in the production of this book. We especially appreciate Ms. Aakanksha and Ms. Priya for their continued support.

We are sure that this book will attract scientists, undergraduates, graduates, and postdocs who are working on fungal diversity, ecology, and biocontrol mechanisms.

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K. M. Rodrigues and B. F. Rodrigues

Abstract

Coastlands are ecologically sensitive habitats undergoing continuous transformation. They connect the terrestrial and marine ecosystems and impart several ecological services. However, they are susceptible to natural and anthropogenic disturbances that affect the structural stability and vegetation of the dunes. Hence, there is an urgent need to conserve and restore these habitats. Arbuscular mycorrhizal (AM) fungi are essential to soil microorganisms involved in plant community establishment. In coastal dunes, they play a vital role in nutrient cycling and aggregation of sand particles. Therefore, a survey of AM fungal diversity from coastal dunes is necessary to stabilize and conserve dune systems.

Keywords

Dunes · Dune vegetation · Sand aggregation · Disturbances · Arbuscular mycorrhizal fungi · Conservation

14.1 Introduction

Coastlands are highly organized natural dynamic systems undergoing continuous change due to geomorphological processes and varying climatic conditions. Coastal land is characterized by a stressful environment with low fertility, high salinity, intermittent drought, variable temperatures, and an unstable sandy substrate (Yamato et al. 2012; Cui et al. 2016). Dunes are generally of two types viz., an arid interior desert of continental landmasses such as Sahara in Africa or Victoria desert in Australia, and the coastal dunes that occur along the Atlantic and Pacific coast of

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North America and the Australian coast. In Asia, the coastal dunes are found in Japan, India, and several other countries. The coastal dunes have the sand as a byproduct of weathered rocks from inland regions eroded by rain and wind. Additionally, the wave action and sea currents are responsible for shifting sand between the seafloor, beach, and dunes. Such habitats have coarse sand with low levels of inorganic nutrients (Desai and Untawale 2002).

14.2 Coastal Dune Vegetation

Plant species found in coastlands are specifically adapted to the persisting extreme environmental conditions. Characteristic vegetation has adapted to temperate and tropical dunes. Members of *Poaceae* are dominant plant species in temperate dunes, while plant members of *Asteraceae*, *Convolvulaceae*, *Fabaceae*, and *Poaceae* are predominant in tropical dunes (Sridhar 2009). Usually, a transition in coastal plant species is found in the dune ecosystem corresponding to the environmental gradient with distance from the sea, the vegetation closest to the seaside experiencing the most stressful conditions (Yamato et al. 2012). Dune vegetation is usually arranged into three main zones—pioneer zone, foredunes, and hinddunes—that are roughly parallel to the coastline.

Closest to the sea is the pioneer zone, extending landward from the debris line at the top of the beach in the area of the foredune or frontal dune. Only specific pioneer plants such as *Spinifex littoreus* L. (Poaceae), *Ipomoea pes-caprae* (L.) R. Br. (*Convolvulaceae*) and few other herbaceous species that can withstand the harsh conditions colonize areas exposed to salt spray, sandblast, strong winds, and flooding by the sea. These plants have specialized structures such as a waxy coating on stems and leaves; these are prostrate, and have well developed and rapidly spreading root systems. The creeping stems or stolons can interconnect, so if one part is buried in shifting sand or is uprooted, another part continues to grow; and so serve to stabilize the sand, forming and building the dunes (https://www.ehp.qld.gov.au/coastal/ecology/beaches-dunes/coastal_dunes.html).

Plant species on the foredunes, or frontal dunes, are more complex than those in the pioneer zone. Scrub or woodland plants occupy the foredunes as more nutrients support the growth of such plants. Plant species in this zone are generally semi-permanent windswept and include *Spermacoce stricta* L. f. (*Rubiaceae*), *Leucas aspera* (Willd.) Link (*Lamiaceae*), *Vitex negundo* L. (*Lamiaceae*), *Clerodendrum inerme* (L.) Gaertn. (*Lamiaceae*), *Casuarina equisetifolia* L. (*Casuarinaceae*), besides vines and few herbs.

The hind dune is occupied by more complex and developed vegetation such as stunted trees, low shrubs, and forest plants. Protected by the strong winds and salt spray experienced closer to the beach, this area is more protected, making it easier for less hardy and specialized trees to grow and survive. Plants in this zone include *V. negundo* L. (*Lamiaceae*), *C. inerme* (L.) Gaertn. (*Lamiaceae*), *Anacardium occidentale* L. (*Anacadiaceae*), *Pandanus tectorius* Parkinson (*Pandanaceae*), *C. equisetifolia* L. (*Casuarinaceae*), *Cocos nucifera* L. (*Arecaceae*). The occurrence of these plants in the hind dunes results in more humus and organic matter, thus providing sufficient nutrients for the growth of more plant species. Eventually, plant communities are established in this region, further contributing to the nutrients of the area (Desai 1995; http://www.beachapedia.org/Vegetation; http://www.ozcoasts.gov.au/indicators/beach_dune.jsp).

14.3 Importance of Coastal Dune Systems and Its Vegetation

Dunes serve as natural buffers, protecting the landward side from storm tides, waves, and wind action. Stabilization of large, mobile dunes by the vegetation cover has been recognized as an effective means to decelerate the inland movement of sand (Woodhouse 1982). The dune vegetation traps and holds windblown sand grains on the foredunes. It contains many native plant species and is valued as a habitat of its natural biodiversity. Loss of dune vegetation can trigger dune erosion wherein the exposed, dry sand particles are flown by high-velocity winds resulting in the shifting of large volumes of sand, sometimes forming large depressions in the dunes. This drifting sand can smother the surrounding vegetation, cover roads and properties. Erosion of beaches and foredunes may be a natural process and is often balanced by the supply of sand from the nearshore continental shelf to the beaches by currents and waves.

In some cases, sand from adjacent dunes may replenish beach systems during erosion periods. However, anthropogenic activities can also induce dune erosion. Some of the human activities which can lead to deterioration include grazing, fires, tracks, and foot traffic resulting in loss of dune vegetation; urban development on foredunes; clearance of dunes for agriculture, etc., ultimately result in dune degradation (http://www.ozcoasts.gov.au/indicators/beach_dune.jsp). Therefore it is crucial to protect dune vegetation.

14.4 Arbuscular Mycorrhizal (AM) Fungi

The survival of plants under harsh coastal conditions depends upon their mutualistic associations with soil microorganisms such as AM fungi, rhizobia, and endophytes. AM fungi are ubiquitous obligate soil fungi belonging to phylum *Glomeromycota* (Redecker et al. 2000) that form symbiotic associations with majority of land plants (Smith and Read 2008); developing intra-radical structures (hyphae, arbuscules, vesicles) in the cortical cells and extra-radical structures (hyphae, spores) in soil. The extra-radical mycelial network in the rhizosphere facilitates soil nutrients, especially phosphorus (P) (Bucher 2007). In addition to nutrient acquisition, other benefits provided to the host include plant tolerance to biotic and abiotic stress (Bennett and Bever 2007); improved nutrient cycling (Tiwari and Sati 2008); improved soil stability, binding, and water retention (Rillig and Mummey 2006; Bedini et al. 2009); and bioremediation of soil (Leyval et al. 1997). In return, the fungal partner receives carbon compounds from the host plant (Brundrett 2009).

Thus, under extreme environmental conditions, AM fungi play a significant role in pioneering the vegetation and bringing about ecosystem stability. They also play a vital role in the primary and secondary succession of plant species, including uptake of water and nutrients by plants in coastal dunes (Beena et al. 2000a).

14.5 AM Fungi and Its Benefits to Dune Ecosystems

AM fungi are widespread in coastal dune systems (Stürmer and Bellei 1994). Coastal dunes favor the occurrence of AM fungi mainly because of low phosphorus content (Ranwell 1972). Mycorrhizal diversity in dunes results in an increase in the longevity of feeder roots and improvement in soil texture through the increased aggregation of soil particles (Nasim 2005). AM fungi provide P to plants that enable AM plants to grow better than non-mycorrhizal plants when P is limiting. An increase in yield or biomass of AM plants is often observed compared to non-mycorrhizal plants (Mosse 1972). Increased nutrient supply, salinity tolerance, reduced abiotic stresses, and formation of wind-resistant soil aggregates are the significant benefits derived by the dune vegetation through AM fungal association (Gemma and Koske 1989). Read (1989) showed that plant communities in successional dune chronosequences are governed by an interaction between biotic and physicochemical properties of the sand. Not only does the composition of plant species change with the seasons and age of the dune systems, but also the association with soil microorganisms changes with succession because of an increase in organic matter, improved substrate stability, and nutrient enrichment (Koske and Gemma 1997). The most crucial function of mycorrhizal fungi at the ecosystem scale is their contribution to soil structure. Soil aggregation is also vital in non-agricultural ecosystems, such as in the context of the restoration of disturbed lands, erosion control, global change, or soil carbon storage (Niklaus et al. 2003). Many physical, chemical, and biological factors (and their interactions) contribute to soil aggregation, yet AM fungi are particularly significant among the biological aspects. They create conditions contributing to the formation of microaggregates, and they chemically enmesh and stabilize microaggregates and smaller macroaggregates into macro aggregate structures. Localized drying of soil near the roots promotes binding between root exudates and clay particles, directly facilitating microaggregate formation (Augé et al. 2004). Besides this, other functions of AM in dune ecosystems include increased resistance of plants to root pathogens and increased plant tolerance to salt and drought stress (Koske et al. 1975; Nelson 1987; Newsham et al. 1995; Koske et al. 2004).

An environment is created through close mutualistic associations between plants and soil microorganisms that allow the dune systems to persist. Therefore, understanding AM associations with dune vegetation and their distribution in dunes is required for wise management, restoration, and revegetation of disturbed dunes.

14.6 AM Fungi in Dunes and Their Association with Dune Vegetation

Coastal plant communities are faced with poorly formed soils with shifting sands and nutrient-deficit environments. Dune vegetation is essential for the formation and preservation of dunes and the protection of the coastline. Dune vegetation is highly adapted to salt-laden winds of the coast and maintains the foredunes by holding the sand in the dunes, trapping sand particles blown up from the beach, and aid in repairing the degraded dunes (Desai and Untawale 2002). Coastal dunes face harsh environments, where AM fungi play an essential ecological role in promoting growth, establishment, and survival of plant species that colonize dunes (Dalpe 1989; Tadych and Błaszkowski 2000).

The extra-matrical hyphal network of AM fungi is involved in the transfer of nutrients from the soil nutrient deficiency zones formed around the plant roots. They play a vital role in building and maintaining the structure of dunes and in the stabilization of dune vegetation. Jehne and Thompson (1981) reported a considerable amount of hyphal connections of fungal mycelium in the top 20 cm of mobile sand in Cooloola (Queensland), Australia. These fungi bind loose sand grains into larger aggregates through secretion of hydrophobic 'sticky' glycol-proteinaceous substance known as 'glomalin,' which improves soil stability, binding, and water retention, limiting dune loss or erosion (Bedini et al. 2009). Forster and Nicolson (1981) reported that 1.5% of the aggregate sand grains reach a diameter of 2 mm in Scotland dunes.

AM fungal association is common in dune plants. Stahl (1900) and Asai (1934) initially reported AM associations with roots of dune plants. Since then, several surveys have been carried out in temperate and subtropical regions (Lee and Koske 1994a); a few from the tropical coast of Hawaiian Islands (Koske 1988; Koske and Gemma 1996), India (Mohankumar et al. 1988; Kulkarni et al. 1997; Visalakshi, 1997; Rodrigues and Jaiswal 2001) and Singapore (Louis 1990). AM fungi have also been reported from beaches in Australia (Koske 1975; Jehne and Thompson 1981; Brockhoff 1985), as well as from maritime dunes of other countries (Nicolson and Johnston 1979; Koske and Halvorson 1981; Giovannetti and Nicolson 1983; Bergen and Koske 1984; Sylvia 1986). Studies on AM fungal associations in dune plants in Australia, USA, India, and Europe indicate that dominant dune plants and pioneer grasses are generally associated with AM fungi. These fungi help in dune stabilization through the successful establishment of plant communities by improving their nutrient status. Koske (1988) reported that among all other mycorrhizal types, the AM fungi benefit from plant species in dune ecosystems.

The most common AM fungal genera in coastal dune systems worldwide are *Acaulospora*, *Gigaspora*, *Glomus,* and *Scutellospora*. Variations in AM fungal spore densities per unit volume of soil have been reported, depending upon different factors such as season, host genotype and phenology, and environment, ranging from 1 to >300, 100 g-1 soil (Maun 2009). The greater the number of viable propagules, the more the chances of forming symbiosis and utilizing its benefits by plants. *Scutellospora erythropa* in the Bahamas, *Acaulospora scrobiculata* and

Gigaspora albida in North America (Koske and Walker 1984), *Glomus* spp. in Japanese dunes (Abe et al. 1994) formed the most dominant AM fungal species in dune systems. Koske (1987) reported 14 AM fungal species from the sandy soils of Wisconsin, with *Glomus etunicatum* being the most frequently isolated species. Lee and Koske (1994b) observed *Gigaspora* was the dominant AM genus in dunes of the Atlantic coast of U.S. Kulkarni et al. (1997) recorded 16 AM species in Mangalore coast of Karnataka with *Gigaspora ramisporophora*, *Glomus albidum*, *G. clarum*, and *Scutellospora gregaria* as dominant species. Rodrigues and Jaiswal (2001) recorded AM association in six plant species growing on dune vegetation of Goa and reported the presence of three AM fungal genera viz., *Acaulospora*, *Glomus*, and *Sclerocystis*. Stutz et al. (2000) observed that the taxonomic range of AM fungi was mostly limited to *Glomaceae* and *Acaulosporaceae* at El Socorro, near Ensenada, Baja California.

The roots of dune plants are intimately associated with AM fungi (Koske and Gemma 1997). Most plant species that colonize dunes are known to have AM symbioses with variable degrees of root colonization (Druva-Lusite and Ievinsh 2010). However, on heterogeneous and unpredictable coastal ecosystems, AM colonization might be expected to be more significant in the more stable habitats (Ievinsh 2006). Giovannetti and Nicolson (1983) reported the presence of *Glomus mosseae* and G. fasciculatum in Italian dunes. They observed that plant species of cosmopolitan families were found to be heavily colonized by AM fungi. Mobile to stable dunes of the Gulf of Mexico revealed AM colonization in 97% of plant species (Corkidi and Rincón 1997). El-Giahmi et al. (1976) studied AM fungi from coastal sandy soils of Libya, wherein most of the host plant species recorded colonization levels between 40% and 60%. Giovannetti (1985) reported higher AM fungal root colonization in plant species belonging to families *Asteraceae*, *Papilionaceae*, and *Poaceae* on the Italian dunes.

Koske (1975) reported higher spore density in older, more stabilized dunes than in younger dunes in Australia. The highest AM fungal spore density was recorded in the rhizosphere of *Ammophila breviligulata* dominating the dune vegetation in Rhode Island (Koske and Halvorson 1981). Bergen and Koske (1984) investigated the occurrence of AM fungi from dunes of Capecod-Massachusetts. They recorded five AM species belonging to the genus *Gigaspora* in association with roots of *Ammophila breviligulata*, and reported *Gi. gigantea* as the dominant species. Sylvia (1986) observed spatial and temporal distribution of AM fungi associated with *Uniola paniculata* in the foredunes of Florida. The study also reported that the spore densities in non-vegetated areas adjacent to vegetated dunes averaged less than 6% of the spore densities found in the rhizosphere of sea oats. Beena et al. (2001b) reported the occurrence of 30 AM species from 28 dune plant species belonging to 14 families from the West Coast of India. *Ipomoea pes-caprae* and *Launaea sarmentosa* growing on dunes of the West Coast of Karnataka harbored 41 and 28 AM species, respectively (Beena et al. 1997, 2000a). Ragupaty et al. (1998) reported 14 AM species in the rhizosphere of 31 plant species from dunes in Tamil Nadu. Khan (1971) studied illustrations of six types of AM fungal spores from West Pakistan soils. Mohankumar et al. (1988) studied the distribution of AM fungi in the sandy beaches of the Madras coast and reported the presence of *Entrophospora* and *Glomus* species. According to them, soil temperature and moisture status influenced the colonization of AM fungi in coastal soils.

Several edapho-climatic factors are known to affect spore germination, root colonization, and efficiency of AM fungi. In the dunes, nutrient input is intermittent by salt spray or precipitation (Kellman and Roulet 1990), and organic matter serves as a significant energy resource (John et al. 1983). The main growth constraints faced by the dune vegetation are the low availability of N, P, K, water, and organic matter (Maun 1994). According to van der Valk (1974), calcium (Ca) and magnesium (Mg) are usually adequate for plant growth, while N, P, and K are limiting in dune systems. Preferential association of AM fungi was observed with decaying organic matter (John et al. 1983). The high organic matter resulted in increased growth of AM fungi in soil (Joner and Jakobson 1995). A significant difference in the edaphic factors or determinants such as moisture, pH, P, Na, K, and N between naturally vegetated and non-vegetated dunes of the West Coast of India is observed in several studies (Beena et al. 1997; Kulkarni et al. 1997; Beena et al. 2000a, b). Organic matter supplies P for acid and alkaline phosphatases of AM fungi. Alkaline phosphatase activity of AM fungi decreased in soil devoid of organic matter (Sridhar 2009). Uptake of Ca by AM fungi plays a vital role in P and water uptake by plants (Pai et al. 1994). Enhancing P nutrition is a significant benefit to the host plant in an AM fungal association. In coastal dunes, the level of available P to the plants is typically deficient. The hardship imposed on plants by such low P levels is compounded by the downward mobility of P in the soil. Available P is removed from near the absorbing surface of roots creating a narrow depletion zone. The AM fungal extra-radical hyphae can cross this zone and provide the plant with P (Koske 1984). AM fungi also play a significant role in N acquisition by plants (Hodge et al. 2010; Smith et al. 2011). However, plant species differ in their mycorrhizal response in complex ways across N and P availability (Hoeksema et al. 2010). It is reported that AM abundance decreases with higher P (Richardson et al. 2011) and N concentration (Treseder 2004) in soil, while soil pH affects fungal community composition (Dumbrell et al. 2010). According to Sieverding (1991), one of the most critical soil physicochemical factors appears to be pH. Many fungi show a wide tolerance to distinct pH ranges, which is reflected in the occurrence of species rather than genera (Koske 1987). While species from different genera can be found in soils covering a broad pH range, others like *Glomus mosseae* have only been reported from soils with pH values greater than 5.5 (Sieverding 1991). According to Stürmer et al. (2018), soil pH appears as the primary factor influencing the dominance of *Gigasporaceae* and *Glomeraceae* in dunes worldwide. Temperature also seemed to be the main factor determining the structure and distribution of AM fungal communities along the latitudinal temperature gradient (Koske 1987; Davison et al. 2015). Although variations in the behavior of AM fungal species are known to exist concerning other soil factors (heavy metals, texture, moisture, nutrient levels, salinity, etc.), the significance of these for AM diversity in native or natural habitats is still poorly understood. The distribution of AM fungal species appears to be more closely related to host plant, soil structure, and environmental conditions than to competition by other AM species (http://mycorrhizae.ifas.ufl.edu/Files/THESIS.pdf).

Stürmer and Bellei (1994) studied the composition and seasonal variation of AM spore populations in dune soils on the Island of Santa Catarina, Brazil. They observed that spore numbers of *Glomus constrictum*, *G. etunicatum*, and *Acaulospora* species were highest in winter, whereas *Gigaspora albida* peaked in the spring. Beena et al. (1997) reported that AM root colonization peaked during post-monsoon, while AM fungal species richness and spore diversity were highest during monsoon. A two-year seasonal study by Beena et al. (2000a) on the coastal dunes of the West coast of India revealed that the percent AM root colonization was least during monsoon and highest during post-monsoon. Still, the mean spore density was least during post-monsoon and highest during the summer. *Glomus* was the most common genera, with mean species richness being highest in *I. pes-caprae* (Beena et al. 2001a).

Burrows and Pfleger (2002) reported that plant cover could be predictive of spore volume or number. Nicolson (1960) examined AM colonization in dune grass in a more complex dune system and found a dramatic increase in the AM activity from the foredunes to the recently fixed dunes. According to Mayr (1965), disturbed habitats result in a reduced number of AM fungal propagules because of the reduction in host plants. Disturbance of soil leads to elimination or decrease in the number of viable propagules of AM fungi (Reeves et al. 1979). Sylvia and Will (1988) reported changes in AM populations and other soil microorganisms in replenished sand planted with *Uniola paniculata* and *Panicum* species. They observed a shift in dominant AM fungi found in the planted zone concerning those in established dunes. Beena et al. (2000a) reported that the vegetation cover, AM fungal colonization, species richness, and diversity were more significant in moderately disturbed dunes than in severely disturbed dunes of the West Coast of India.

Generally, the AM fungal diversity appears to be greater in more stabilized dunes than in younger or disturbed dunes (Giovannetti and Nicolson 1983). AM associations can be potential determinants of plant diversity in ecosystems. Since plant species differ in their response to AM fungi in the soil, the presence or absence of AM has been linked to the composition of plant communities that grow in the dunes (Francis and Read 1995). AM fungi can probably modify the structure and functioning of a plant community in a complex and unpredictable way (Read 1990). Any shift in the AM fungal population can result in survival, competition, and floristic diversity of plant community composition, causing changes in the ecology of natural habitats (Miller and Allen 1992). Therefore, knowledge of the different factors influencing the population biology of AM fungi is essential for their utilization in conservation of the environment (Allen 1991), biotechnology (Mulongoy et al. 1992), or in sustainable agriculture (Bethlenfalvay and Linderman 1992).

14.7 Conclusions

Being major ecological communities of marine ecosystems, the coastal dunes are of great significance throughout the world. However, they are susceptible to continuous environmental and anthropogenic interferences. The stabilization of dunes depends on the successful establishment of plant communities, and native plant species have a high potential to withstand these disturbances. Hence, there is great potential for rehabilitation of dunes by manipulating dune microbial resources especially AM fungal associations, to accelerate the growth of dune vegetation that will help to conserve and restore the coastal dunes.

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