Preface

Research has provided clear indications on how mycorrhizal symbioses are central to the multitrophic interactions that occur underground and how these impact the plants aboveground. Conversely, changes that occur aboveground influence development and functioning of mycorrhizas and their relationships with other soil organisms. However, information is still fragmentary concerning the ecological relevance of such phenomena in ecosystem dynamics and stability. In contrast, substantial progress has been made during the last few years in knowledge about the processes regulating mycorrhiza establishment and their function as mutualistic symbioses, as well as their ecological diversity. This has furthered understanding of: (1) the basic biological mechanisms sustaining compatibility and synergism between the interacting organisms, as well as the genetic and cell programmes involved, (2) the impact of symbiotic relationships in terms of individual fitness in ecosystems, and (3) the role of the symbioses in the evolution of plant life styles.

This book integrates present-day knowledge from well-known research groups on some of the topics which are at the forefront of mycorrhizal research, and in particular those related to cell programmes driving mycorrhiza formation and function, the processes sustaining symbiotic mutualism, stress response mechanisms in mycorrhizal symbionts, and the diversity and ecological impacts of mycorrhizal systems. As a general introduction, the first chapter by D. Atkinson places mycorrhizal research in the global context of the evolution of agricultural polices and practices. Methodologies used for improving food production in intensive agriculture are questioned, and evidence is provided for the need to enhance the role of mycorrhizas in order to improve food quality and reduce environmental damage.

The enigma of mutualism evolution is evoked in the second chapter, from the viewpoint of biological altruism in beneficial microbes. Because of the cellular and molecular convergence that can be found between mycorrhizal and rhizobial symbioses, N.A. Provorov and N.I. Vorobyov take the comprehensively studied legume–rhizobia symbioses as the basis to discuss the role of selective pressures in maintaining genes for beneficial traits in soil microbial populations. For a long time, evolutionary research was focussed mainly on antagonistic symbioses but, as de Bary had already pointed out at the end of the nineteenth century, a gradient should exist between microbial parasites that help their partners and those that destroy them. In this context, early fungal–plant interactions are determinant

factors for the outcome of symbiotic interactions and, in the following chapter, V. Gianinazzi-Pearson et al. review recent knowledge about the molecular dialogue involved in the primary steps essential to the symbiotic process.

In established mycorrhizal associations, bidirectional exchange of nutrients and other benefits that occur require the formation of symbiotic interfaces resulting from morphophysiological changes in both plant and fungal tissues. The next two contributions are devoted to ongoing non-targeted research to identify transcripts (M. Arlt et al.) and proteins (G. Recorbet and E. Dumas-Gaudot) involved in mycorrhizal functioning, whilst in the sixth chapter N. Ferrol and J. Perez-Tienda consider in detail the function of specific molecular and cellular modifications in the coordinated nutrient exchange across interfaces between the two symbionts. This is followed by a chapter where E.J. Grace et al. evoke the possibility of exploring functional diversity in plant responsiveness to mycorrhiza at the molecular level, in the light of mechanisms for P uptake via mycorrhizal and direct uptake pathways.

Mycorrhizas play a key role in regulating abiotic and biotic stresses to plants, particularly at the rhizosphere level, and this positively impacts on safe food production and bioremediation programmes. Research on mechanisms underlying such beneficial effects has developed considerably in recent years, and two chapters focus on how mycorrhizal fungi may interfere with heavy metal transport within plant tissues (M. González-Guerrero et al.) or induce plant resistance against pathogens (M.J. Pozo et al.).

Recognition of the Glomeromycota as a separate phylum of true fungi (and the extension of their genetic variability by combining molecular and morphological taxonomy) is an important advance in the last decade. J.B. Morton reviews in his chapter the persisting discord between rRNA gene and morphology-based phylogeny, and discusses how this can be overcome within the framework of a balanced multidisciplinary approach.

The mycorrhizal condition is the state of the large majority of plants under most ecological conditions, and therefore these symbioses are a key element in ecosystem functioning. The importance of a spatial context for the understanding of the ecology and evolution of organisms has become increasingly clear. B.J. Pickles and co-workers examine methodological approaches for spatial analysis of mycorrhizal fungi, and show how their application could yield more information about communities than that obtained from simple species abundance and frequency data. Potential mechanisms responsible for generating and maintaining spatial variation in populations and communities of mycorrhizal fungi at different scale levels (root, community, landscape) are then reviewed by B.E. Wolfe et al., and the difficulty in linking such mechanisms to observed spatial patterns is discussed.

Ecological disturbance, whether natural or through human activity, also impacts on the diversity of mycorrhizal fungi, and ecological resilience of these symbionts is essential for sustaining productivity. S.W. Simard considers response diversity of mycorrhizal fungi to disturbance by wildfire or cutting in forest ecosystems, and the impact on survival and growth rate of regenerating vegetation. Likewise, in their chapter, R.J. Bills and J.C. Stutz monitor species richness of mycorrhizal fungi associated with plants in disturbed urbanized, as compared to natural desert, sites.

Drivers of alterations in community structure of mycorrhizal fungi need to be identified. In the forest ecosystem example, reduction in fungal diversity may be avoided when forest floor and key functional groups of plants are maintained. Such an observation is of primary importance in defining optimal forest management practices. The final chapter by A. Morte and collaborators illustrates how successful management strategies can ensure the introduction and production of the desert truffle, which could represent an interesting model for managing production of other edible mycorrhizal fungi.

In conclusion, interest in mycorrhizal symbioses continues to expand and to encompass an increasing range of disciplines. Plants and mycorrhizal fungi have co-evolved in continuous interaction with their abiotic and biotic environments, developing a wide range of coordinated mechanisms which considerably favour the production of primary biomass. Information about such mechanisms is of outstanding importance for promoting sustainable practices in plant production systems as well as for ecosystem conservation and restoration schemes. In conclusion, the efficient management of mycorrhizal systems has the potential to favour the sustainable production of quality foods while ensuring environmental quality for future generations.

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