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Edited by J. C. Frankland, N. Magan and G. M. Gadd

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Despite an upsurge in national and international debate on environmental issues since the Earth Summit in Rio de Janeiro in 1992, fungi, vital to the functioning of terrestrial and aquatic ecosystems, are rarely mentioned. This volume helps redress this imbalance by considering fungi in the context of the impact of mankind's activity on their habitats. The presentation of experimental evidence is a major feature of the volume. Contributions on the effects of global warming, UV-B radiation, atmospheric and terrestrial pollutants, deforestation in the tropics, loss of biodiversity, genetic engineering and chaos theory ensure a topical and balanced coverage with both ecological and physiological viewpoints being represented. This timely review will be of interest to all mycologists and those ecologists concerned with environmental change.

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Fungi and environmental change

*SYMPOSIUM OF
THE BRITISH MYCOLOGICAL SOCIETY
HELD AT CRANFIELD UNIVERSITY
MARCH 1994*

EDITED BY

J. C. FRANKLAND, N. MAGAN &
G. M. GADD

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Preface

The 'Environment' is now on political agendas, and it is time the mycological voice was heard in the upsurge of national and international debates that have followed in the wake of the 1992 Earth Summit at Rio de Janeiro. Despite worldwide concern over environmental changes, fungi vital to the functioning of ecosystems are rarely mentioned.

This is the first symposium volume to focus on fungi in relation to man-made changes in the natural environment. It comprises papers presented at a British Mycological Society Symposium held at Cranfield University, UK, in 1994. The authors, all actively engaged in mycological research, cover widely diverse but highly topical subjects such as global warming, rising sea levels and destruction of rainforests. Speculation is bound to be found, but experimental evidence has been included wherever possible. Selection will also be apparent. The number of mycologists in this field is not great and many environmental problems remain untouched. Our aim is to stimulate thought on some of the issues of the day, and to point to the need for more research at every level, from field recording to cell physiology.

In Chapter 1 Lonsdale and Gibbs discuss predicted changes in global climate in relation to associations between fungal pathogens and perennial, woody hosts, and the extent to which the geographic range and pathogenic activity of the fungus (they do not always coincide) might alter. This contrasts with Pettitt and Parry's account in Chapter 2 of the potential effects of long-term climatic change, particularly temperature, on a disease of an annual, herbaceous plant, *Fusarium* foot rot of winter wheat in the UK, for which predictive modelling is more feasible.

Depletion of ozone in the stratosphere by the use of chlorofluorocarbons and other chemicals, leading to an increase in UV-B radiation, is a major threat to all living organisms. Experiments on the sensitivity of both pathogenic and saprotrophic foliar fungi to UV-B are described by Ayres and his co-authors (Chapter 3). They also draw attention to

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indirect effects that this radiation can have on both living and dead plant materials on which these fungi are growing and competing.

A rise in sea levels in certain regions is forecast to be one of the most dramatic consequences of global warming, and Rotheroe (Chapter 4) describes the particular vulnerability of the mycoflora of UK sand dunes to such events. Ing in Chapter 5 also warns of threats to fungal diversity, quoting evidence from long-term recording of European macrofungi. A decline in the numbers of fruit bodies is ascribed to both loss of specific habitats and pollution. To what extent fruiting reflects the abundance and vigour of vegetative mycelia in the natural environment is still largely unknown.

Pollution is by no means a new area of research for mycologists, but changes in the relative importance of different types of pollutant and the increasing efficiency of analytical techniques justify the inclusion of several chapters on this theme. Chapters 6, 7 and 8 are all on atmospheric pollutants, including dry-deposited sulphur dioxide, which has been less well studied than wet deposition, although probably of greater relevance (see Boddy *et al.*). Ozone and nitrogen oxide, both currently of particular concern, are also among the pollutants discussed by Magan *et al.* and by Shaw.

The effects of environmental change on mycorrhizal associations are particularly difficult to interpret. Typically, mycorrhizas are present when mineral nutrients are already limiting to plant growth. Furthermore, stress factors can act directly or indirectly on the symbiotic partners. Colpaert and Van Tichelin (Chapter 9) discuss these complex interactions in relation to both arbuscular-vesicular and ectomycorrhizal fungi, emphasising the importance of the external mycelium, and supporting their observations with case studies on excess nitrogen, elevated carbon dioxide and metal toxicity.

Chapter 10 is also concerned with mycorrhizas but from the practical viewpoint of how to manage the ecological disaster regions of the humid tropics. In this extensive review, Janos discusses rehabilitation of the deforested, low productivity land that has been stripped of surface soil and of its normal reservoirs of mycorrhizal inoculum.

The impact of changes in land use on beneficial fungi in soil continues to be the theme in Chapter 11. Here Bardgett shows how communities and interactions of saprotrophic fungi, bacteria and fauna could be altered if the UK government implements a policy to reduce overgrazing by sheep and resulting loss of biodiversity in the hill grasslands of northern England. As he points out, the changes could have profound effects on nutrient cycling and organic matter decomposition.

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The Chernobyl accident of 1986 brought home to many the irrelevance of national boundaries to the spread of aerial pollution, the ramifications of contamination within the various food chains, and the inequalities in pollutant accumulation by different components of the biota. For example, some fungi accumulate exceptionally high amounts of radiocaesium, particularly in the fruit bodies (basidiomes) of certain basidiomycetes. This has been a useful attribute in studies of Chernobyl fallout, reviewed by Dighton and Terry (Chapter 12). These authors have also explored in laboratory experiments the influx and immobilisation of caesium by grassland and forest fungi, comparing mycorrhizal and saprotrophic species, and also uptake by mycorrhizal and non-mycorrhizal plants. They suggest that, on some sites, much of the fallout could be immobilised in fungal mycelium with implications for grazing animals.

Although aquatic fungi are far outnumbered by terrestrial species, they fulfil a vital function as saprotrophs in freshwater and marine ecosystems, and any perturbations to their activities can affect plant and animal communities. Bermingham in Chapter 13 reviews previous studies on the effects of pollutants on freshwater hyphomycetes, and discusses the results of her own investigations on the effects of effluent from abandoned coal mines contaminated with iron and manganese.

Fundamental physiological processes that underlie the reactions and resistance of fungi to some stress factors in the environment are the subject of Chapters 14 and 15. First, Adler reviews the adaptations of fungi to high concentrations of sodium chloride, important with respect to soil salinisation. Secondly, Gadd and his co-workers discuss sequestration, mobilisation and transformation of toxic metals and metalloids, all processes of environmental importance since they influence the mobility and toxicity of these pollutants.

This volume would be unbalanced without some reference to lichens, well known to be sensitive indicators of pollution, although, as shown in Brown's review (Chapter 16), investigators have concentrated almost entirely on the photosynthetic component of the symbiosis. He shows that there is scope for more research on the fungal partner, which acts as the interface with the immediate environment.

The potential role of fungi in environmental 'bioremediation' is still largely untapped. Their particular versatility, simple structure, and the ease with which they can be cultured in bulk quantities fit them well for commercial use. Singleton and Tobin in Chapter 17 discuss the possibility of using them to remove metals from effluents, pointing out that some

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species are as effective in removing metals, including radionuclides, as commercial ion-exchange resins.

Uncontrolled environmental hazards of anthropogenic origin have been the subject of most of the preceding chapters, but advances in genetic engineering of microorganisms, as yet almost confined to bacteria and unicellular yeasts, are likely to expose filamentous fungi in the near future to more monitored perturbations. Whipps and his co-authors (Chapter 18) discuss the state of the art and consider it is only a matter of time before genetically manipulated fungi are ready for 'risk assessment'. The need to increase our understanding of the ecology of populations and communities of fungi and associated organisms will then be paramount.

Rayner was challenged to answer the question: 'Has chaos theory a place in environmental mycology?' In an intellectually stimulating, final chapter, he argues that, as mycelial fungi are non-linear, indeterminate systems, chaos (non-linear) theory does not have just a place in environmental mycology but is fundamental to it.

The British Mycological Society gratefully acknowledges sponsorship of this Symposium by Glaxo Holdings plc and Cranfield Environment. The first editor (JCF) also thanks the staff of Merlewood Research Station for all their support, and NM is grateful for assistance given by students in the Applied Mycology Group, Biotechnology Centre, Cranfield University during the Symposium.

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