



MYCOLOGY AND MICROBIOLOGY

(A Textbook for UG and PG Courses)

C. Manoharachary

K.V.B.R. Tilak

K.V. Mallaiah

I.K. Kunwar

Mycology and Microbiology

The Authors

Prof. C. Manoharachary Ph.D., D.Sc. was Head, Dept. of Botany, Osmania University, Hyderabad, did post doctoral work at UK, USA, and Germany, is NASI Senior Scientist - Platinum Jubilee Fellow. Guided 46 Ph.D. students, published over 435 research papers and authored/edited 24 books. He bagged several National awards and is Fellow of eight national academies.

Prof. K.V.B.R. Tilak Ph.D. was Head, Division of Microbiology, IARI, New Delhi and NASI Senior Scientist and Platinum Jubilee Fellow. He was DAAD Fellow and Humboldt Fellow, Germany. Guided 30 Ph.D. students and published over 250 research papers. He is Fellow of six Academies and honoured with several national awards.

Prof. K.V. Mallaiah, Ph.D. is founder of Department of Microbiology and served as Head, Depts. of Microbiology and Botany, Nagarjuna University, Guntur, A.P. He has guided 20 Ph.D. students and published over 150 research papers. He has authored ten books. He is Fellow of four academic societies.

Dr (Mrs) I.K. Kunwar D.Phil. was Visiting Research Associate in USA and Research Scientist in the Department of Botany, Osmania University, Hyderabad. She has published more than 125 research papers and authored/edited 5 books.

Mycology and Microbiology

(A Textbook for UG and PG Courses)

C. Manoharachary

Department of Botany, Osmania University,
Hyderabad-500007, Telangana

K.V.B.R. Tilak

Department of Botany, Osmania University,
Hyderabad-500007, Telangana

K.V. Mallaiah

Department of Botany, Nagarjuna University,
Guntur, A.P.

I.K. Kunwar

Department of Botany, Osmania University,
Hyderabad-500007, Telangana



Published by:

SCIENTIFIC PUBLISHERS (INDIA)

Jodhpur

Delhi

—

—

5 A, New Pali Road

4806/24, Ansari Road

P.O. Box 91

Daryaganj

Jodhpur 342 001

New Delhi - 110 002

E-mail: info@scientificpub.com

Website: www.scientificpub.com

© 2016, Authors

All rights reserved. No part of this publication or the information contained herein may be reproduced, adapted, abridged, translated, stored in a retrieval system, computer system, photographic or other systems or transmitted in any form or by any means, electronic, mechanical, by photocopying, recording or otherwise, without written prior permission from the authors.

Disclaimer: Whereas every effort has been made to avoid errors and omissions, this publication is being sold on the understanding that neither the editors (or authors) nor the publishers nor the printers would be liable in any manner to any person either for an error or for an omission in this publication, or for any action to be taken on the basis of this work. Any inadvertent discrepancy noted may be brought to the attention of the publishers, for rectifying it in future editions, if published.

ISBN: 978-81-7233-991-3 (PB)

978-81-7233-989-0 (HB)

eISBN: 978-93-86102-13-3

Printed in India

**This book is dedicated to the Mycologists
and Microbiologists of India**

Foreword

It is a matter of not only of great honor but of rare pride and privilege to write a foreword for the book 'Mycology and Microbiology' authored by illustrious teachers and researchers and long time associates and friends and philosophers in the field of mycology and microbiology by Prof. C. Manoharachary, Prof. K.V.B.R. Tilak, Prof. K.V. Mallaiah and Dr. I.K. Kunwar. The fungi are achlorophyllous and eukaryotic organisms which possess primarily chitinous cell wall and absorptive nutrition. They are ubiquitous and cosmopolitan in distribution. They colonize diversified habitats viz., water, soil, air, litter, dung, keratin, living plants, seed, leaf surface, rhizosphere, oceans as well as other specialized ecological niches as extremophiles. Around 1.5 million fungi are estimated to exist in the world but only around 29,000 are reported from India. The fungal diversity is intimately limited to ecosystem function. Out of one lakh species of fungi only 5-7% have been grown artificially and therefore, require both *ex-situ* and *in-situ* conservation strategies. Fungi find their utilization in industry, agriculture, medicine, food industry, textiles, dyes, bioremediation, biotransformation, genetics, coal solubilization, natural cycling, biofertilizers, biocontrol and in many other ways. Thus Fungal Biotechnology has become an integral part of human welfare.

Biology of microorganisms and their study is important. The importance of microbes has been known since times immemorial. Microbes such as bacteria, actinomycetes, cyanobacteria and others are ubiquitous and are indispensable in biochemical cycles, form integral part of soil component and soil health besides being present in other habitats including in human digestive system. Microbes are useful in plant growth, nitrogen fixation, food industry, phosphate solubilization, antibiotic production, abiotic stress, production of enzymes, accumulation of osmoregulants, genetics and in several other activities related to human welfare. No doubt that some pathogenic microbes and fungi cause diseases of plants, animals and humans but this does not undermine their utility aspects.

This book entitled "Mycology and Microbiology" is the outcome of their long teaching experience, knowledge and expertise. This is the essence of the dedicated career of these eminent mycologists and microbiologists. I congratulate them for this laudable, significant and unique contribution. I am sure that this text book which condenses the vast knowledge into 40 chapters, soaked in equally vast expertise, will be highly useful for teachers, researchers, P.G. and U.G. students, R & D institutes, Universities and others. They need to be complimented and congratulated for their attempt which translates their teaching acumen into words of wisdom. I wish the authors and scientific publishers, India, Jodhpur all the success.



Prof. T. N. Lakhanpal
(Prof. Emeritus)
Department of Bio-Sciences
H.P. University
Shimla

Preface

Fungal biology is an interesting branch of science as it plays an important role in the development of the biomedical and biotechnology sectors. Fungi are non-chlorophyllous living eukaryotes which are variable in form, behavior, function and life cycle. Fungi have created themselves specialized status of a kingdom by virtue of possessing well defined, typically chitinized cell wall and absorptive nutrition besides being ubiquitous as saprobes, symbionts, parasites or hyperparasites and cosmopolitan in distribution. Many natural processes are dependent on the interaction between fungi and their environment. Fungal kingdom is diverse and around 1.5 million is the estimated number. Around one lakh fungi are described from the world and 29000 fungal species are reported from India. India is the cradle for fungi, microbes, plants and other living organisms and this hidden wealth needs to be explored for human welfare in order to provide food security, nutritional security, health security and environmental security for the growing population.

The variety and galaxy of fungi and their natural beauty occupy prime place in the biological world. Fungi are not only beautiful but play a significant role in the daily life of human beings besides their utilization in industry, agriculture, medicine, food industry, textiles, bioremediation, biocontrol, natural cycling of elements, as biofertilizers, in biotransformation, genetic manipulation and in many other ways. Fungal biotechnology has become an integral part of human welfare. Fungi are well recognized to produce a wide variety of chemical structures, several of which are most valuable pharmaceuticals, agrochemicals and industrial products. *Saccharomyces cerevisiae* was the first eukaryote available with a genome sequence. The recent developments in molecular biology have allowed mycologists to discover the unexplored or hidden wealth of fungi for the benefit of humanity.

Microorganisms are microscopic organisms and include bacteria viruses, microalgae, yeasts, actinomycetes, protozoans and others. Microbes have the ability to breakdown complex chemical substances including hydrocarbons, pesticides, wastes and convert them into simpler substance. These are known to help in recycling of chemical elements and incorporate them into the soil, water and air. Autotrophic bacteria and algae play an important role in photosynthesis which is a food and oxygen generating process. Microbes have applied value and play important role in human welfare. Microbes are used in the synthesis of acetone, glycerin, organic acids, vitamins, amino acids, enzymes, alcohols, vaccines, antibiotics, drugs, in agriculture, bioremediation and others.

There are several good text books available in Mycology and Microbiology and all such text books have worthy material. In recent times there have been changes in the nomenclature, classification, life cycle studies, relationship between asexual and sexual stages, origin and phylogeny, diversity, biotechnology and molecular approaches. This book includes a number of chapters dealing with fungal biology, diversity, taxonomy, biotechnology and topics of interest in mycology along with microbial diversity, their structure, reproduction, function and importance. The subject content suffices the needs of U.G. and P.G. syllabus of UGC, ICAR institutions and others. It is an outcome of our committed sincere and humble attempt of our 35 to 40 years of teaching and research experience and expertise.

We sincerely hope that this text book will be highly useful to the student community, teaching fraternity, young and budding researchers, candidates preparing for competitive examinations and others. We hope that this humble academic venture will be worthy addition in understanding fungi and microbes.

We express our thanks to Mr. Y.S.N. Murthy for his valuable technical help. Our grateful thanks are to Scientific Publishers (India), Jodhpur, India for their keen interest in bringing out this academic contribution and their concerted efforts are laudable. Our thanks are to the teaching community, research scholars, students, eminent mycologists and all others of India for their encouragement. We welcome your suggestions and critical opinion to for further improvement in adding new knowledge. We assure you that next edition will take care all such opinions.

C. Manoharachary
K.V.B.R. Tilak
K.V. Mallaiah
I.K. Kunwar

Contents

A. MYCOLOGY

1.	THE FUNGI	1-3
2.	HISTORY OF MYCOLOGY	4-10
3.	GENERAL CHARACTERS OF FUNGI	11-37
	Nutrition of Fungi	26
	Growth of fungi	27
	Reproduction in Fungi	29
4.	INTERNATIONAL CODE OF NOMENCLATURE FOR ALGAE, FUNGI AND PLANTS; TAXONOMY OF FUNGI	38-46
	Principles	38
	History	39
	Taxonomy of Fungi	40
5.	ZOOSPORIC FUNGI (CHYTRIDIOMYCOTA: KINGDOM-STRAMENOPILA)	47-84
	Phylum - Chytridiomycota	48
	Class – Chytridiomycetes	50
	Kingdom – Stramenopila	51
	Class – Hyphochytridiomycetes	58
	Phylum – Oomycota	59
	Class – Oomycetes	59
	Important Genera	62
6.	ZYGOMYCOTA	85-109
	Class- Zygomycetes	85
	Class - Trichomycetes	94
	Important Genera	96

7.	ASCOMYCOTA	110-145
	Classification	117
	Class - Hemiascomycetes	118
	Class – Plectomycetes	119
	Class – Pyrenomycetes	119
	Class – Discomycetes	123
	Class – Loculoascomycetes	126
	Class- Laboulbeniomycetes	128
	Important Genera	129
8.	BASIDIOMYCOTA	146-189
	Classification	152
	Class – Teliomycetes	154
	Class – Hymenomycetes	158
	Class- Gasteromycetes	166
	Important Genera	171
9.	ANAMORPHIC FUNGI	190-215
	Class - Blastomycetes	196
	Class - Hyphomycetes	197
	Class - Coelomycetes	197
	Important Genera	199
10.	GLOMEROMYCOTA	216-220
	Arbuscular Mycorrhiza	216
	Benefits derived from Mycorrhiza by Host Plants	218
	Morphological Diversity in Arbuscular Mycorrhizal Fungi	218
11.	MYXOMYCOTA	221-224
	Class - Myxomycetes	221
	Plasmodiophoromycota	224

B. CURRENT TOPICS OF IMPORTANCE

12.	PHYLOGENY, EVOLUTION AND ORIGIN OF FUNGI	239-242
	Phylogenetic Hypotheses, Evolutionary Relationships and Circumscription of the Fungi	240
13.	BIODIVERSITY AND BIOTECHNOLOGY OF FUNGI	243-254
	What is Biodiversity?	243

	Biodiversity of Fungi	243
	Fungal Biotechnology	247
14.	AEROMYCOLOGY	255-258
15.	GENERAL ACCOUNT OF PLANT DISEASES CAUSED BY FUNGI AND THEIR CONTROL	259-265
	Some Important Fungal Diseases of Crop Plants	260
	Control of Plant Diseases Caused by Fungi	263
16.	ENDOPHYTIC FUNGI – SOME GLIMPSES	266-268
17.	FUNGAL ECOLOGY	269-278
18.	FUNGAL GENETICS - GENERAL ACCOUNT	279-283
19.	DIVERSITY AND CONSERVATION OF FUNGI	284-292
	Diversity of Fungi	285
	Conservation of Fungi	289
20.	LICHENS - STRUCTURE, REPRODUCTION, ECOLOGICAL AND ECONOMIC IMPORTANCE	293-304
	Occurrence	294
	Thallus Structure	295
	Nutrition and Growth	297
	Reproduction	297
	Classification of Lichens	299
	Some Important Genera of Lichens	300
	Importance of Lichens	301
21.	MUSHROOM – CULTIVATION AND APPLICATION	305-317
	Button Mushroom	306
	Oyster Mushroom	310
	Paddy Straw Mushroom	313
22.	MYCORRHIZA	318-326
	Mycorrhiza Types	318
	Benefits Derived from Mycorrhiza by Host Plants	322
	Morphological Diversity in AM Fungi	322
	Ecological Diversity in AM Fungi	323
23.	SEXUAL REPRODUCTION OF FUNGI – RECENT TRENDS	327-341
	Sexual Reproduction	328

	Taxonomic Implications of Sexual Reproduction	330
	Fungal Mating-Type Locus	341
	Genetic Diversity in Microsporidia	341
24.	FUNGI IN MISCELLANEOUS SUBSTRATES	342-346
	Thermophillic Fungi	342
	Psychrophillic Fungi	344
	Coprophilous Fungi	345
	Phyllosphere Fungi	345
	Fungi in the Atmosphere	345
	Soil Fungi	346
	Marine Fungi	346
25.	ENTOMOGENOUS FUNGI	347-354
	Effect of Environmental Factors	349
	Development of Entomogenous Fungi for Pest Control	350
	Entomophthorales	353
26.	MYCOTOXIGENIC FUNGI – MYCOTOXINS	355-364
	Mycotoxins	356
	Mycotoxicoeses	362
27.	INTERACTION OF FUNGI WITH HIGHER PLANTS – SOME PALEOBOTANICAL GLIMPSES	365-366
28.	KERATINOPHILIC FUNGI – GENERAL ACCOUNT	367-369
	Dermatophytes	368
29.	MYCOLOGICAL METHODS - COLLECTION, OBSERVATION AND ISOLATION	370-378
	Collection	370
	Observation	372
	Isolation Techniques	375

C. MICROBIOLOGY

30.	THE LIVING KINGDOM	397-400
31.	HISTORICAL DEVELOPMENTS IN MICROBIOLOGY	401-414
	Beginnings of Microbiology	401
	Golden Age of Microbiology	403
	Pioneers of Microbiology	405

	Era of Molecular Biology	409
	Developments of Soil Microbiology during 20th Century	410
	Prospects and Challenges	413
32.	MICROSCOPY	415-424
	Bright Field Microscope	415
	The Phase Microscope	417
	The Electron Microscope	418
	The Dark-Field Microscope	418
	Microscopic Examination of Bacteria	419
	Differential Stains	421
33.	BACTERIA	425-494
	Components of Bacterial Cell	426
	Plasmids	433
	Cultivation and Nutrition of Bacteria	438
	Utilization of Nutritional and Energy Sources by Bacteria	444
	Growth of Bacteria	445
	Classification of Bacteria	452
	Reproduction in Bacteria	470
	Biotechnology of Bacteria	476
34.	VIRUSES	495-506
	Viruses	495
	Bacteriophage	497
	Virus Multiplication	498
	Classification	502
	Cultivation of Viruses	505
35.	OTHER MICROORGANISMS	507-529
	Actinobacteria (Actinomycetes)	507
	Archaeobacteria	509
	Bioprospecting of Archaea	514
	Mollicutes	515
	Rickettsiae	518
	Chlamydiae	518
	Prions	519
	Cyanobacteria (Blue-Green Algae)	520

	Selected Members of Cyanophyceae	525
	Protozoa	526
36.	DISEASES CAUSED BY BACTERIA AND OTHER PROKARYOTES	530-544
	Bacterial Diseases	531
	Viral Diseases	536
	Plant Diseases Caused by Spiroplasmas	540
37.	DIVERSITY AND CONSERVATION OF MICROORGANISMS	545-552
	Biodiversity	545
	Conservation	545
	Utilization of Microbial Diversity for Sustainable Agriculture	550
38.	MOLECULAR METHODS FOR THE ANALYSIS OF MICROBIAL COMMUNITIES	553-556
	Molecular Techniques to Study Natural Microbial Communities	553
39.	SOME ASPECTS OF APPLIED MICROBIOLOGY	557-581
	Metabolism	557
	Antibiotics	561
	Environmental issues	563
	Soil remediation	564
	Immunology	564
40.	LIFE CYCLES IN MICROBES AND FUNGI	570-582
	Life cycles in fungi	570
	Asexual life cycle in fungi	573
	GLOSSARY	583-607