



title: Modern Soil Microbiology Books in Soils, Plants, and the Environment ; V. 56
author: Elsas, J. D. van
publisher: CRC Press
isbn10 | asin: 0824794362
print isbn13: 9780824794361
ebook isbn13: 9780585158396
language: English
subject Soil microbiology, Molecular microbiology.
publication date: 1997
lcc: QR111.M58 1997eb
ddc: 579/.1757
subject: Soil microbiology, Molecular microbiology.

Modern Soil Microbiology

BOOKS IN SOILS, PLANTS, AND THE ENVIRONMENT

- Soil Biochemistry, Volume 1*, edited by A. D. McLaren and G. H. Peterson
Soil Biochemistry, Volume 2, edited by A. D. McLaren and J. Skujins
Soil Biochemistry, Volume 3, edited by E. A. Paul and A. D. McLaren
Soil Biochemistry, Volume 4, edited by E. A. Paul and A. D. McLaren
Soil Biochemistry, Volume 5, edited by E. A. Paul and J. N. Ladd
Soil Biochemistry, Volume 6, edited by Jean-Marc Bollag and G. Stotzky
Soil Biochemistry, Volume 7, edited by G. Stotzky and Jean-Marc Bollag
Soil Biochemistry, Volume 8, edited by Jean-Marc Bollag and G. Stotzky
Soil Biochemistry, Volume 9, edited by G. Stotzky and Jean-Marc Bollag
Organic Chemicals in the Soil Environment, Volumes 1 and 2, edited by C. A. I. Goring and J. W. Hamaker
Humic Substances in the Environment, M. Schnitzer and S. U. Khan
Microbial Life in the Soil: An Introduction, T. Hattori
Principles of Soil Chemistry, Kim H. Tan
Soil Analysis: Instrumental Techniques and Related Procedures, edited by Keith A. Smith
Soil Reclamation Processes: Microbiological Analyses and Applications, edited by Robert L. Tate III and Donald A. Klein
Symbiotic Nitrogen Fixation Technology, edited by Gerald H. Elkan
SoilWater Interactions: Mechanisms and Applications, Shingo Iwata and Toshio Tabuchi with Benno P. Warkentin
Soil Analysis: Modern Instrumental Techniques, Second Edition, edited by Keith A. Smith
Soil Analysis: Physical Methods, edited by Keith A. Smith and Chris E. Mullins
Growth and Mineral Nutrition of Field Crops, N. K. Fageria, V. C. Baligar, and Charles Allan Jones
Semiarid Lands and Deserts: Soil Resource and Reclamation, edited by J. Skujin
Plant Roots: The Hidden Half, edited by Yoav Waisel, Amram Eshel, and Uzi Kafkafi
Plant Biochemical Regulators, edited by Harold W. Gausman
Maximizing Crop Yields, N. K. Fageria

- Transgenic Plants: Fundamentals and Applications*, edited by Andrew Hiatt
- Soil Microbial Ecology: Applications in Agricultural and Environmental Management*, edited by F. Blaine Metting, Jr.
- Principles of Soil Chemistry: Second Edition*, Kim H. Tan
- Water Flow in Soils*, edited by Tsuyoshi Miyazaki
- Handbook of Plant and Crop Stress*, edited by Mohammad Pessarakli
- Genetic Improvement of Field Crops*, edited by Gustavo A. Slafer
- Agricultural Field Experiments: Design and Analysis*, Roger G. Petersen
- Environmental Soil Science*, Kim H. Tan
- Mechanisms of Plant Growth and Improved Productivity: Modern Approaches*, edited by Amarjit S. Basra
- Selenium in the Environment*, edited by W. T. Frankenberger, Jr., and Sally Benson
- Plant-Environment Interactions*, edited by Robert E. Wilkinson
- Handbook of Plant and Crop Physiology*, edited by Mohammad Pessarakli
- Handbook of Phytoalexin Metabolism and Action*, edited by M. Daniel and R. P. Purkayastha
- Soil-Water Interactions: Mechanisms and Applications, Second Edition, Revised and Expanded*, Shingo Iwata, Toshio Tabuchi, and Benno P. Warkentin
- Stored-Grain Ecosystems*, edited by Digvir S. Jayas, Noel D. G. White, and William E. Muir
- Agrochemicals from Natural Products*, edited by C. R. A. Godfrey
- Seed Development and Germination*, edited by Jaime Kigel and Gad Galili
- Nitrogen Fertilization in the Environment*, edited by Peter Edward Bacon
- Phytohormones in Soils: Microbial Production and Function*, W. T. Frankenberger, Jr., and Muhammad Arshad
- Handbook of Weed Management Systems*, edited by Albert E. Smith
- Soil Sampling, Preparation, and Analysis*, Kim H. Tan
- Soil Erosion, Conservation, and Rehabilitation*, edited by Menachem Agassi
- Plant Roots: The Hidden Half, Second Edition, Revised and Expanded*, edited by Yoav Waisel, Amram Eshel, and Uzi Kafkafi
- Photoassimilate Distribution in Plants and Crops: Source-Sink Relationships*, edited by Eli Zamski and Arthur A. Schaffer
- Mass Spectrometry of Soils*, edited by Thomas W. Boutton and Shinichi Yamasaki
- Handbook of Photosynthesis*, edited by Mohammad Pessarakli
- Chemical and Isotopic Groundwater Hydrology: The Applied Approach*,

Second Edition, Revised and Expanded, Emanuel Mazor
*Fauna in Soil Ecosystems: Recycling Processes, Nutrient Fluxes, and
Agricultural Production*, edited by Gero Benckiser
Soil and Plant Analysis in Sustainable Agriculture and Environment, edited
by Teresa Hood and J. Benton Jones, Jr.
Seeds Handbook: Biology, Production, Processing, and Storage: B. B. Desai,
P. M. Kotecha, and D. K. Salunkhe

Modern Soil Microbiology, edited by J. D. van Elsas, J. T. Trevors, and E. M. H. Wellington

Growth and Mineral Nutrition of Field Crops: Second Edition, N. K. Fageria, V. C. Baligar, and Charles Allan Jones

Fungal Pathogenesis in Plants and Crops: Molecular Biology and Host Defense Mechanisms, P. Vidhyasekaran

Additional Volumes in Preparation

Plant Pathogen Detection and Disease Diagnosis, P. Narayanasamy
Agricultural Systems Modeling and Simulation, edited by Robert M. Peart and R. Bruce Curry

Agricultural Biotechnology, edited by Arie Altman
Plant-Microbe Interactions and Biological Control, edited by Gregory J. Boland and L. David Kuykendall

Handbook of Soil Conditioners, edited by Arthur Wallace and Richard E. Terry

Modern Soil Microbiology

Edited by
Jan Dirk van Elsas

*Soil Biotechnology Group
Research Institute for Plant Protection (IPO-DLO)
Wageningen, The Netherlands*

Jack T. Trevors

*Department of Environmental Biology
University of Guelph
Guelph, Ontario, Canada*

Elizabeth M. H. Wellington

*Department of Biological Sciences
University of Warwick
Coventry, United Kingdom*



MARCEL DEKKER, INC.
NEW YORK BASEL

Library of Congress Cataloging-in-Publication Data

Modern soil microbiology / edited by Jan Dirk van Elsas, Jack T. Trevors, Elizabeth M. H. Wellington

p. cm. (Books in soils, plants, and the environment: v. 56)

Includes bibliographical references and index

ISBN 0-8247-9436-2 (alk. paper)

1. Soil microbiology. 2. Molecular microbiology. I. Elsas, J. D. van (Jan D.). II. Trevors, Jack T. III. Wellington, E. M. H. (Elizabeth M. H.). IV. Series.

QR 111.M58 1997

597'.1757dc21

97-12600

CIP

The publisher offers discounts on this book when ordered in bulk quantities. For more information, write to Special Sales/Professional Marketing at the address below.

This book is printed on acid-free paper.

Copyright © 1997 by MARCEL DEKKER, INC. All Rights Reserved.

Neither this book nor any part may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying, microfilming, and recording, or by any information storage and retrieval system, without permission in writing from the publisher.

MARCEL DEKKER, INC.

270 Madison Avenue, New York, New York 10016

<http://www.dekker.com>

Current printing (last digit):

10 9 8 7 6 5 4 3

PRINTED IN THE UNITED STATES OF AMERICA

PREFACE

Soil microbiology is a discipline that describes the numbers, fate, activity, and interactions of microorganisms present in soil, and how they are affected by their environment. The soil microbial community is largely responsible for the cycling of carbonaceous, nitrogenous, and phosphorous compounds. Soil microorganisms can be involved in plant-pathogenic reactions, as well as in biological transformations of xenobiotic compounds added to soil. Soil also represents a natural reservoir of genetic information and soil organisms, many of which are unculturable and hence unknown.

There are good reasons to study and understand the principles underlying soil microbiological phenomena. Understanding the function of the soil ecosystem in relation to ever changing soil conditions is key to understanding the basic mechanisms of soil productivity. This is important in light of the urgency to change agricultural practices and also because of current problems of xenobiotic compounds in soils. The capacity of soil microbial populations to cope with xenobiotic and other stresses the possible perturbations caused by pollution, intense agricultural practice, or changing land use are of major interest. In addition, the possibility of involvement of nonculturable or minute cell fractions in these

and other important soil processes presents an intriguing topic for innovative research.

Recent developments in the application of molecular biological techniques to ecological questions have revolutionized concepts in soil microbial ecology. In particular, soil DNA and RNA extraction, nucleic acid reassociation, determination of G + C content of whole microbial populations, specific hybridization and polymerase chain reaction (PCR) techniques, cloning and sequencing, denaturing gradient gel electrophoresis (DGGE) of 16S rDNA based soil DNA amplicons, as well as reporter gene technology, have proven to be powerful tools for the assessment of the ecology of microorganisms in their natural environment. These as well as techniques based on the detection of other cellular macromolecules, such as fatty acid lipids, have also provided new insight into elucidation of the nonculturable fraction (the silent majority) in soil microbial populations and have shed light on the quantity and activity of the culturable bacterial fractions.

In addition, the molecular biology of the starvation and stress survival programs in certain nondifferentiating soil bacteria is beginning to be elucidated, as is the response of bacteria to environmental triggers such as those occurring in bulk soil or in the rhizosphere. Knowledge of the effect of the soil environment on the physiological state of bacteria in soil is an important developing area of research, and interesting information on the effects of different root parts versus bulk soil have been obtained.

The issue of putative biosafety problems associated with the release of genetically modified microorganisms to soil has spurred research on the extent to which gene transfer between microorganisms takes place in soil as affected by soil factors. These studies have also provided insight into the role gene transfer plays in the evolution of microorganisms in their natural environment.

In light of the intrinsic complexity of soil and the potential offered by several recent exciting methodological developments, soil microbiology can be considered one of the last frontiers in science. There has been great progress lately, and even greater progress will be made in the near future in addressing and unraveling some of the great unknowns of soil microbiology.

The novel techniques applied recently to soil and new insights into the diversity as well as physiology of bacteria in this habitat represent knowledge

not presently covered in any other textbook. This text provides a description of currently accepted principles of soil microbiology, updated and combined with insights obtained via the use of molecular techniques. The intended readership are graduate and undergraduate students as well as professionals who require a quick entry into this fascinating intersection of classical soil microbiology and rapidly evolving molecular biology applied to soil microbial ecology.

The first section describes accepted concepts of soil microbiology, picturing the soil and rhizosphere as habitats for microbes to live in, discussing different soil microbial groups (bacteria, fungi, protozoa, and nematodes), and microbial

processes and interactions. The second section is devoted to the composition and activity (gene expression) of soil microbial populations, as determined by molecular techniques. This new information is integrated with current knowledge on soil microbiology. These chapters are unique in that no other current soil microbiology volume has managed to cover all the different new developments. The final section addresses a series of applied aspects of soil microbiology. Here, basic microbial ecology in areas such as the ecology of plant pathogenesis, bioremediation of soil, perturbations by heavy metal pollution, and soil manipulation via plowing or manuring is discussed.

We would like to thank all the authors who contributed to this text for their expertise and patience. Special thanks are also due to the editors at Marcel Dekker, Inc. for their excellent work.

JAN DIRK VAN ELSAS

JACK T. TREVORS

ELIZABETH M. H. WELLINGTON

CONTENTS

Preface	iii
Contributors	xv
Section I. Introductory Chapters	
1. Soil as an Environment for Microbial Life	1
<i>G. Stotzky</i>	
1. Introduction	1
2. Inoculation of Soil	2
3. Soil Physicochemical Characteristics that Affect Bacterial Growth and Survival	4
4. Microhabitats in Soil	6
5. Clay Minerals and Soil Microbes	9
6. Heterogeneity of Microhabitats in Soil	11
7. Manipulation of Physicochemical and Biological Factors in Soil	11
8. Conclusions	18
References	19

2. The Rhizosphere as a Habitat for Soil Microorganisms	21
<i>Jan Sørensen</i>	
1. Introduction	21
2. Structure and Chemistry of the Rhizosphere	22
3. Microbial Populations in the Rhizosphere	29
4. Prospects in Rhizosphere Microbiology: Revival of the Microscope	38
Acknowledgments	42
References	42
3. Culturable and Nonculturable Bacteria in Soil	47
<i>Lars Reier Bakken</i>	
1. Introduction	47
2. The Cultured Bacteria	48
3. Direct Observations of Whole Bacterial Communities	49
4. Filterability, Cell Constituents, and Culturability	50
5. Filterability and Metabolic Activity	53
6. The Starvation Response of Bacteria	54
7. Novel Methods	58
References	59
4. The Fungi in Soil	63
<i>Greg Thorn</i>	
1. Introduction	63
2. Taxonomic Diversity	67
3. Communities of Soil Fungi	73
4. Fungal Numbers and Biomass	74
5. The Roles of Soil Fungi	76

6. Mycorrhizae	83
7. Interactions of Fungi with Other Soil Organisms	95
8. Miscellaneous Topics in Soil Fungi	103
9. Conclusions	107
Acknowledgments	108
References	108
5. Ecology and Biology of Soil Protozoa, Nematodes, and Microarthropods	129
<i>Richard D. Bardgett and Bryan S. Griffiths</i>	
1. Introduction	129
2. Protozoa	129

3. Nematodes	137
4. Microarthropods	144
Acknowledgments	152
References	152
6. Interactions Between Microbe-Feeding Invertebrates and Soil Microorganisms	165
<i>Bryan S. Griffiths and Richard D. Bardgett</i>	
1. Introduction	165
2. Microfauna (Nematodes and Protozoa)-Microbial Interactions	166
3. Microarthropod (Collembola and Mite)-Microbial Interactions	171
Acknowledgments	177
References	177
7. Microbial Processes Within the Soil	183
<i>James I. Prosser</i>	
1. Introduction	183
2. Microcosm or Field Measurements	185
3. Soil Heterogeneity	187
4. General Activity	192
5. Specific Activity	197
6. Growth Rates	206
7. Conclusions	211
References	211
8. Microbial Interactions in Soil	215
<i>Jack T. Trevors and Jan Dirk van Elsas</i>	
1. Introduction	215
2. Interactions Between Microorganisms in Soil	217

3. Interactions Between Microorganisms and Plants	225
4. Protozoa as Predators of Bacteria	230
5. Predatory Bdellovibrio	232
6. Bacterial-Fungal Interactions	233
7. Bacterial-Animal Interactions	235
8. Microorganisms-Metal Interactions	236
9. Conclusions	238
Acknowledgment	239
References	239
9. Soil Food Webs and Nutrient Cycling in Agroecosystems	245
<i>Jaap Bloem, Peter de Ruiter, and Lucas Bouwman</i>	
1. Introduction	245
2. Microbes, Microbivores, and Mineralization in Microcosms	247

3. Microbes, Microbivores, and N Mineralization in Arable Fields Under Conventional and Integrated Management	254
4. Simulation of N Mineralization in the Food Webs of Arable Fields Under Conventional and Integrated Management	264
5. Contributions of Various Organisms to N Mineralization in Different Farming Systems	268
6. Conclusions	273
References	275
Section II. Modern Methodology and Approaches	
10. Direct Approaches for Studying Soil Microbes <i>Anton Hartmann, Bernhard Abmus, Gudrun Kirchhof, and Michael Schlöter</i>	279
1. Introduction	279
2. Conventional Staining Methods for Microorganisms	280
3. Molecular Detection Methods for Microorganisms in Soil	282
4. New Microscopic Techniques and Image Analysis	296
5. Flow Cytometric Analysis of Microbial Populations	299
6. Conclusions	301
References	301
11. Indirect Approaches for Studying Soil Microorganisms Based on Cell Extraction and Culturing <i>Elizabeth M. H. Wellington, Peter Marsh, Joy Elizabeth Margaret Watts, and John Burden</i>	311
1. Introduction	311
2. Approaches to Microbial Biomass Extraction	312
3. Immunomagnetic Capture	318
4. Soil Fractionation	319
5. Enumeration and Isolation of Soil Bacteria	322

6. Conclusions	327
References	327
12a. Microbial Biomarkers	331
<i>J. Alun W. Morgan and Craig Winstanley</i>	
1. Introduction	331
2. Cell Envelope Biomarkers	332
3. General Biochemical Markers	337

4. Nucleic Acid Biomarkers	339
5. Microbial Populations as Biomarkers	346
6. Conclusions	347
Acknowledgment	347
References	347
12b. Application of Denaturing Gradient Gel Electrophoresis and Temperature Gradient Gel Electrophoresis for Studying Soil Microbial Communities	353
<i>Holger Heuer and Kornelia Smalla</i>	
1. Introduction	353
2. Analysis of PCR-Amplified DNA	354
3. Application of DGGE or TGGE Profiling	361
4. Potential Pitfalls of the DGGE or TGGE Analysis	367
5. Conclusion and Comparison of DGGE/TGGE Community Analyses with Other Fingerprinting Techniques	368
Acknowledgments	369
References	370
13. Microbial Diversity in Soil: The Need for a Combined Approach Using Molecular and Cultivation Techniques	375
<i>Werner Liesack, Peter H. Janssen, Frederick A. Rainey, Naomi L. Ward-Rainey, and Erko Stackebrandt</i>	
1. Soil Microbial Communities	375
2. The 16S rRNA Gene as a Biological Marker	378
3. Diversity of Microbial 16S rDNA in Soils	389
4. Methodological Problems of 16S rDNA-Based Studies	409
5. Diversity at the Physiological Level	412
6. Strategies for the Isolation of Microorganisms	417