

# PLANT PARASITIC NEMATODES



Edited by  
**B. M. Zuckerman,**  
**W. F. Mai,**  
and **R. A. Rohde**

*Volume II*

*Cytogenetics,  
Host—Parasite  
Interactions,  
and Physiology*

*Plant Parasitic Nematodes*

*VOLUME II*

**Cytogenetics, Host–Parasite Interactions,  
and Physiology**

## **Contributors**

ALAN F. BIRD  
C. E. CASTRO  
A. J. CLARKE  
A. F. COOPER, JR.  
K. H. DEUBERT  
C. C. DONCASTER  
BURTON Y. ENDO  
C. D. GREEN  
L. R. KRUSBERG  
N. T. POWELL  
R. A. ROHDE  
AUDREY M. SHEPHERD  
DIETER STURHAN  
C. E. TAYLOR  
I. J. THOMASON  
A. C. TRIANTAPHYLLOU  
S. D. VAN GUNDY  
B. M. ZUCKERMAN

# *Plant Parasitic Nematodes*

*Edited by*

**B. M. ZUCKERMAN**

LABORATORY OF EXPERIMENTAL BIOLOGY  
UNIVERSITY OF MASSACHUSETTS  
EAST WAREHAM, MASSACHUSETTS

**W. F. MAI**

DEPARTMENT OF PLANT PATHOLOGY  
CORNELL UNIVERSITY  
ITHACA, NEW YORK

*and*

**R. A. ROHDE**

DEPARTMENT OF PLANT PATHOLOGY  
UNIVERSITY OF MASSACHUSETTS  
AMHERST, MASSACHUSETTS

**VOLUME II**

**Cytogenetics, Host-Parasite Interactions, and Physiology**

1971



ACADEMIC PRESS New York and London

**COPYRIGHT © 1971, BY ACADEMIC PRESS, INC.**  
**ALL RIGHTS RESERVED**  
**NO PART OF THIS BOOK MAY BE REPRODUCED IN ANY FORM,**  
**BY PHOTOSTAT, MICROFILM, RETRIEVAL SYSTEM, OR ANY**  
**OTHER MEANS, WITHOUT WRITTEN PERMISSION FROM**  
**THE PUBLISHERS.**

**ACADEMIC PRESS, INC.**  
111 Fifth Avenue, New York, New York 10003

*United Kingdom Edition published by*  
**ACADEMIC PRESS, INC. (LONDON) LTD.**  
Berkeley Square House, London W1X 6BA

**LIBRARY OF CONGRESS CATALOG CARD NUMBER: 78-127710**

**PRINTED IN THE UNITED STATES OF AMERICA**

# Contents

LIST OF CONTRIBUTORS	xi
PREFACE	xiii
CONTENTS OF VOLUME I	xv

## GENETICS AND CYTOLOGY

### 13. Genetics and Cytology

*A. C. Triantaphyllou*

I. Introduction—Historical Review	1
II. Gametogenesis and Cytological Features of Reproduction	3
III. The Chromosomes of Nematodes	13
IV. Sexuality	16
V. Hybridization among Nematodes	27
VI. Cytogenetic Aspects of Nematode Evolution	29
References	32

## HOST-PARASITE INTERACTIONS

### 14. Specialized Adaptations of Nematodes to Parasitism

*Alan F. Bird*

I. Introduction	35
II. Morphological and Physiological Adaptations	36
III. Ecological Adaptations: Response to Stress	47
IV. Summary	48
References	48

### 15. Biological Races

*Dieter Sturhan*

I. Introduction	51
II. Sibling Species	53

III. Intraspecific Variation	54
IV. Types of Physiological Variation	59
V. Causes of Variability	61
VI. Methods of Race Identification	62
VII. Genetics of Physiological Characters	63
VIII. Development and Maintenance of Physiological Diversity	65
IX. Terminology	67
X. Conclusion	68
References	69
<b>16. Nematode Enzymes</b>	
<i>K. H. Deubert and R. A. Rohde</i>	
I. Introduction	73
II. Techniques in Enzymic Analysis	74
III. Nematode Enzymes	77
IV. Summary	88
References	89
<b>17. Nematode-Induced Syncytia (Giant Cells). Host-Parasite Relationships of Heteroderidae</b>	
<i>Burton Y. Endo</i>	
I. Introduction	91
II. Nematode Penetration and Migration	92
III. Mechanism of Feeding in the Heteroderidae	93
IV. Stimulation of Galls	94
V. Formation of Syncytia	97
VI. Nature of Resistance	111
VII. Conclusions	114
References	115
<b>18. Interaction of Plant Parasitic Nematodes with Other Disease-Causing Agents</b>	
<i>N. T. Powell</i>	
I. Introduction	119
II. Nematode-Fungus Complexes	120
III. Nematode-Bacteria Interactions	127
IV. Nematode-Virus Relationships	129
V. Some Effects of Complexes on Nematode Populations	131

VI. The Nature of Complexes Involving Nematodes	132
VII. Conclusions	134
References	135
<b>19. Feeding in Plant Parasitic Nematodes: Mechanisms and Behavior</b>	
<i>C. C. Doncaster</i>	
I. Introduction	137
II. Behavior Leading to Feeding	139
III. Pharyngeal Gland Secretions	141
IV. Ingestion	143
References	156
<b>20. Gnotobiology</b>	
<i>B. M. Zuckerman</i>	
I. Introduction	159
II. Methodology	161
III. Applications	171
IV. Conclusions	180
References	180
<b>21. Nematodes as Vectors of Plant Viruses</b>	
<i>C. E. Taylor</i>	
I. Introduction	185
II. The Vectors	187
III. The Viruses	192
IV. Relationships between Viruses and Vector Nematodes	196
V. Ecology and Control	204
References	207

## BIOCHEMISTRY AND PHYSIOLOGY

<b>22. Chemical Composition of Nematodes</b>	
<i>L. R. Krusberg</i>	
I. Introduction	213
II. Inorganic Substances	214



III. Carbohydrates	215
IV. Amino Acids and Proteins	216
V. Lipids	222
VI. Plant Growth Regulators	231
VII. Other	232
VIII. Conclusions	233
References	233
<b>23. Respiration</b>	
<i>R. A. Rohde</i>	
I. Introduction	235
II. Factors Influencing Respiration	237
III. Methods of Measuring Respiration	244
References	245
<b>24. Mating and Host Finding Behavior of Plant Nematodes</b>	
<i>C. D. Green</i>	
I. Introduction	247
II. Sources of Stimulants	248
III. Dissemination of Stimuli	253
IV. Responses to Stimuli	258
V. Discussion	263
References	264
<b>25. Molting and Hatching Stimuli</b>	
<i>Audrey M. Shepherd and A. J. Clarke</i>	
I. Molting	267
II. Hatching	271
References	284
<b>26. Mode of Action of Nematicides</b>	
<i>C. E. Castro and I. J. Thomason</i>	
I. The State of Knowledge	289
II. Gross Effects	290
III. Permeation Characteristics	292
IV. Model Systems	294
V. Hypotheses	295
References	296

**27. Senescence, Quiescence, and Cryptobiosis***A. F. Cooper, Jr. and S. D. Van Gundy*

I. Introduction	297
II. Senescence	299
III. Quiescence	304
IV. Cryptobiosis	310
V. Summary	314
References	315
AUTHOR INDEX	319
SUBJECT INDEX	331

This page intentionally left blank

## List of Contributors

Numbers in parentheses indicate the pages on which the authors' contributions begin.

- ALAN F. BIRD (35), C.S.I.R.O., Division of Horticultural Research, Glen Osmond, South Australia
- C. E. CASTRO (289), Department of Nematology, University of California, Riverside, California
- A. J. CLARKE (267), Rothamsted Experimental Station, Harpenden, Herts., England
- A. F. COOPER, JR. (297), Department of Nematology, University of California, Riverside, California
- K. H. DEUBERT (73), Laboratory of Experimental Biology, University of Massachusetts, East Wareham, Massachusetts
- C. C. DONCASTER (137), Rothamsted Experimental Station, Harpenden, Herts., England
- BURTON Y. ENDO (91), Crops Research Division, Agricultural Research Service, U. S. Department of Agriculture, Beltsville, Maryland
- C. D. GREEN (247), Rothamsted Experimental Station, Harpenden, Herts., England
- L. R. KRUSBERG (213), Department of Botany, University of Maryland, College Park, Maryland
- N. T. POWELL (119), Department of Plant Pathology, North Carolina State University, Raleigh, North Carolina
- R. A. ROHDE (73, 235), Department of Plant Pathology, University of Massachusetts, Amherst, Massachusetts

- AUDREY M. SHEPHERD (267), Rothamsted Experimental Station, Harpenden, Herts., England
- DIETER STURHAN (51), Institute of Nematology, Münster, Westphalia, Germany
- C. E. TAYLOR (185), Scottish Horticultural Research Institute, Invergowrie, Dundee, Scotland
- I. J. THOMASON (289), Department of Nematology, University of California, Riverside, California
- A. C. TRIANTAPHYLLOU (1), Department of Genetics, North Carolina State University, Raleigh, North Carolina
- S. D. VAN GUNDY (297), Department of Nematology, University of California, Riverside, California
- B. M. ZUCKERMAN (159), Laboratory of Experimental Biology, University of Massachusetts, East Wareham, Massachusetts

## Preface

This two-volume treatise was written to provide an up-to-date reference source for students, teachers, and research and extension workers in plant nematology and related fields. Nematological advancements made since the publication of a similar book approximately ten years ago are discussed. A high proportion of the available knowledge obtained during this time has been in such important areas of nematology as ultrastructure, enzymology, chemistry of body composition, culturing, virus transmission, biological races, and nature of plant resistance. Thus, this is the first comprehensive reference work in nematology to include information from these new areas as well as from traditional ones.

An attempt has been made to coordinate and evaluate the phenomenal amount of research data of these years. In order to include the best possible coverage of the many diverse and specialized topics, a number of authors were invited to contribute to the text; many are actively engaged in the field about which they have written. Although each chapter was edited, the data and opinions expressed are those of the contributors.

Volume I includes a discussion of the history of plant nematology, the current status of research, and information pertaining to professional societies and publications. It also deals with nematode morphology, anatomy, taxonomy, and ecology, emphasizing plant parasitic forms and, where pertinent, drawing examples from free-living and animal parasitic nematodes.

Volume II deals with plant parasitic nematode genetics and cytology, host-parasite interactions, biochemistry, and physiology. As in Volume I, useful information relating to free-living and animal parasitic nematodes is included.

We wish to thank the authors for the considerable time spent in preparing their contributions. Such comprehensive treatises of important areas of plant nematology are invaluable to progress in this biological discipline. In fact, without them it would be difficult or impossible for students to become familiar with and research workers to keep abreast of the knowledge in specific areas.

B. M. ZUCKERMAN  
W. F. MAI  
R. A. ROHDE

This page intentionally left blank

# Contents of Volume I

## MORPHOLOGY, ANATOMY, TAXONOMY, AND ECOLOGY

Introduction

*W. F. Mai*

### **Morphology and Anatomy**

Comparative Morphology and Anatomy

*Hedwig Hirschmann*

Nemic Relationships and the Origins of Plant Nematodes

*A. R. Maggenti*

Form, Function, and Behavior

*H. D. Crofton*

### **Taxonomy**

Taxonomy: The Science of Classification

*G. W. Bird*

Taxonomy of Heteroderidae

*Mary T. Franklin*

Taxonomy of the Dorylaimida

*Virginia R. Ferris*

Classification of the Genera and Higher Categories of the Order  
Tylenchida (Nematoda)

*A. Morgan Golden*



**Ecology**

Biotic Influences in Soil Environment

*Richard M. Sayre*

Abiotic Influences in the Soil Environment

*H. R. Wallace*

Diagnostic and Advisory Programs

*K. R. Barker and C. J. Nusbaum*

Population Dynamics

*C. J. Nusbaum and K. R. Barker*

Author Index-Subject Index

# *Genetics and Cytology*

This page intentionally left blank